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Volume 13 MARCH 1929 Number 3

BULLETIN

of the

American Association *of* Petroleum Geologists

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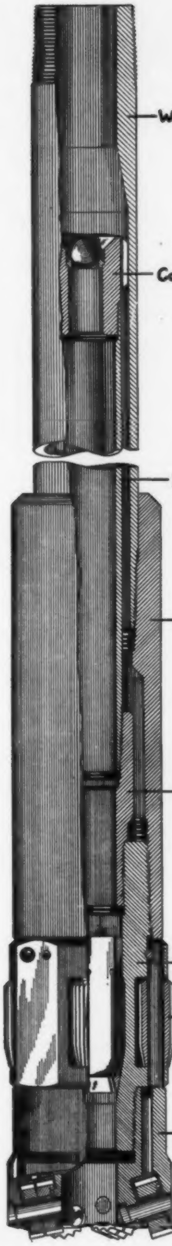

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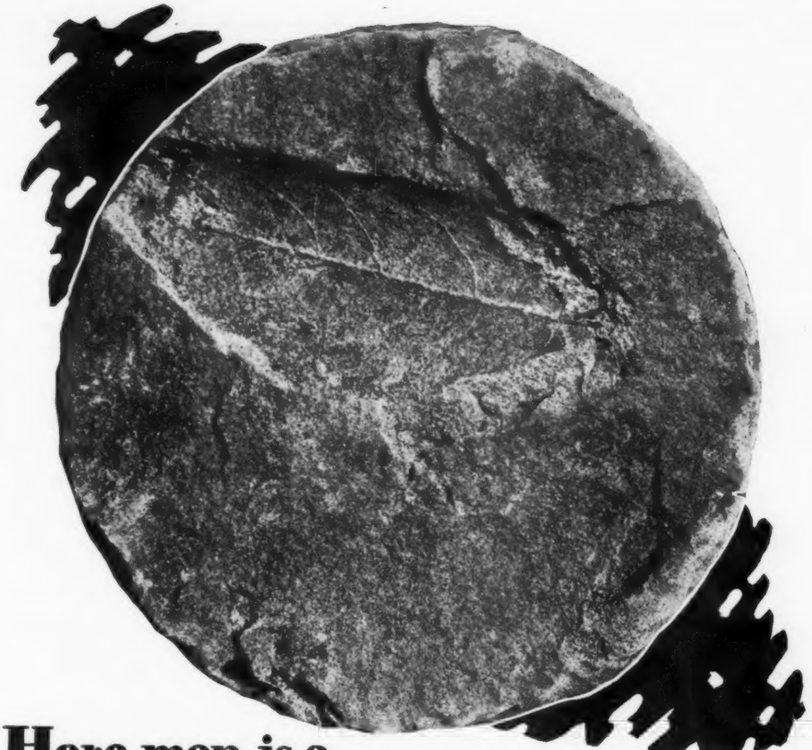

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THE BULLETIN

of the

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The Bulletin of the American Association of Petroleum Geologists is published by the Association on or about the 15th of each month. Editorial and publication office, 504 Tulsa Building, Tulsa, Oklahoma, Post Office Box 1852.

The subscription price to non-members of the Association is $15.00 per year (separate numbers $1.50) prepaid to addresses in the United States, Mexico, Cuba, Porto Rico, Panama Canal Zone, Republic of Panama, Dominican Republic, Canary Islands, El Salvador, Argentina, Bolivia, Brazil, Colombia, Chile, Costa Rica, Ecuador, Guatemala, Honduras, Nicaragua, Peru, Hayti, Uruguay, Paraguay, Hawaiian Islands, Philippine Islands, Guam, Samoan Islands, Balearic Islands, and Spain.

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AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
BOX 1852
TULSA, OKLAHOMA

Entered as second-class matter at the Post Office at Tulsa, Okla., under the Act of March 3, 1879. Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized March 9, 1923.

MID-WEST PRINTING CO., TULSA, OKLA., U. S. A.

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MARCH 1929

TECTONICS OF THE VALLE GRANDE OF CALIFORNIA[1]

BRUCE L. CLARK[2]
Berkeley, California

ABSTRACT

The Valle Grande, of which the Great Valley of California is only a part, is a complex fault trough with zones of faulting bounding its western and southern sides. The writer (1) briefly reviews the structural conditions west and south of the Valle Grande, (2) discusses in some detail the major structures along its borders, (3) describes the character of the San Andreas fault zone, (4) shows that zones of folding along the western border of the Valle Grande are invariably associated with faulting, which can be traced into the zones of faulting that bound the basin on the west, (5) considers the significance of the overlaps and unconformities along the margins of the basin, and (6) points out that along the western border are probable old delta deposits in the Cretaceous and Eocene sediments.

GENERAL STATEMENT

The Great Valley of California, the modern representative of the old Valle Grande, is one of the largest structural valleys in North America, having a length of more than 400 miles and a maximum width of approximately 50 miles (Fig. 1). On the east is the westward-tilted Sierra Nevada block with its high eastern crest breaking off abruptly at a fault scarp; on the west are the Coast Ranges. At the north are the Siskiyou and Klamath mountains, composed very largely of Paleozoic and early Mesozoic rocks, and at the south are the Tehachapi and San Emigdeo mountains, connecting the Coast Ranges with the

[1]A contribution from the Museum of Paleontology, University of California. Read before the Association at the San Francisco meeting, March 23, 1928. Manuscript received by the editor, December 24, 1928.

[2]Department of paleontology, University of California.

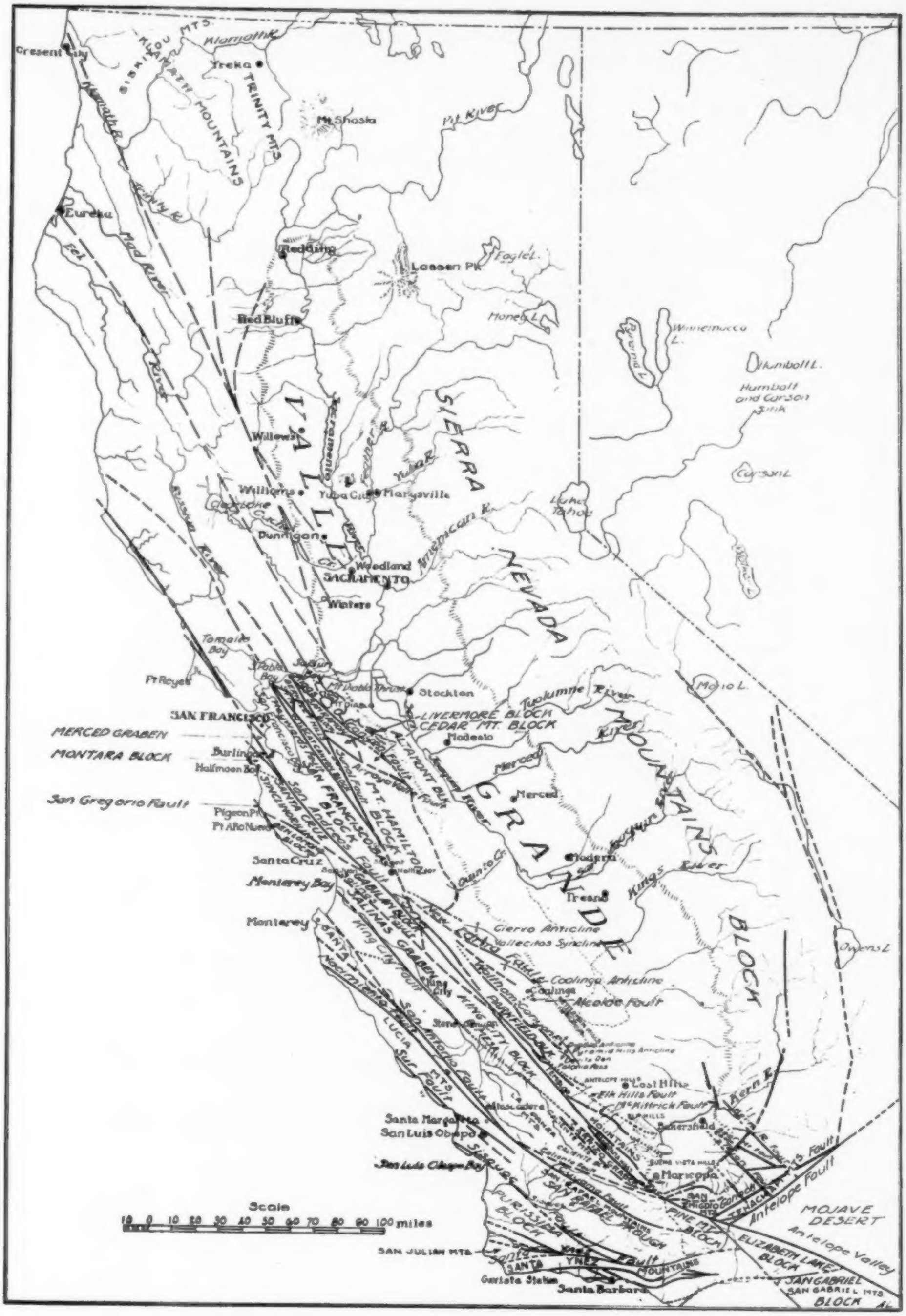

FIG. 1.—Map showing localities and principal primary faults in the Coast Ranges of northern and middle California.

Sierra Nevadas. The northern part of the Great Valley of California is generally referred to as the Sacramento valley, and the southern part as the San Joaquin valley. The boundary between the two may be marked by an east-west line through the junction of the San Joaquin and Sacramento rivers. The two valleys have much in common in their geologic history, and many of the generalizations that apply to one undoubtedly apply to the other.

Very little has been written about the origin of the Valle Grande. In general it has been assumed that here is a good example of a geosyncline, the result of folding, with the geanticline, represented by the Coast Ranges, on the west. Certain writers, however, have recognized the possibility of faulting as an important factor. For example, Turner,[1] in 1893, postulated the probability of a fault under the valley alluvium. Ransome,[2] in his paper, referred to the Great Valley of California as a geosyncline and evidently had the idea that the Coast Ranges on the west represented a corresponding geanticline.

Lawson,[3] in 1908, in discussing the Great Valley, wrote:

> Turner has suggested that the great valley east of the Coast Ranges is determined by a fault. There is some warrant for this view and it is certainly true in part. The very precipitous mountain front which rises from the valley at its southern end is without doubt a degraded fault scarp, though whether this fault or a series of similar faults can be followed along the edge of the mountains is questionable. It is, however, safe to say that the eastern margin of the Coast Ranges represents a line of acute deformation with the probability of that deformation having taken the form of faults in certain places. No one has yet made a sufficiently careful study of the question to make a precise statement possible.

Since the preceding statement was made, a large amount of detailed geologic mapping has been done, especially on the areas surrounding the San Joaquin valley. Practically all this work was by members of the United States Geological Survey. There is little published detailed geological information on the northern Coast Ranges. For that reason the writer will deal mostly with the structures in and around the San Joaquin valley part of the Valle Grande, and will describe only briefly the northern part. Enough work has been done in the north, however,

[1] H. W. Turner, *Amer. Geologist*, Vol. 13 (1893), p. 248.

[2] F. L. Ransome, "The Great Valley of California. A Criticism of the Theory of Isostasy," *Univ. Calif. Pub., Bull. Dept. Geol.*, Vol. 1, No. 14 (1896), pp. 371-428.

[3] A. C. Lawson, *Report of the California Earthquake Commission*, Vol. 1, Pt. 1 (1908), p. 12.

to show that we have there the same types of structures and the same general relation to the surrounding areas as are found in the south.

In a paper of this character, space does not permit a discussion in detail of all the known structures of the Valle Grande. The writer has confined his statement to some of the more salient features which, it is believed, give a clue to the mechanics of the faulting and folding, to the principal periods of crustal movement, and to the general conditions of sedimentation.

The most important general conclusion pertaining to the origin of the Valle Grande is that it is a complex fault-trough. The western margin of this great depression was defined by a series of faults, some of which came into existence at least as early as the beginning of Cretaceous time, and probably earlier; likewise, there is a zone of faulting at the south end near the contact between the marine deposits and the granitic part of the Tehachapi-San Emigdeo area which forms a part of the so-called "knot" to be described later. On the east side of the Valle Grande, for a considerable distance from north to south, the alluvium of the valley laps upon the Sierra Nevada block, and in these places wherever Cretaceous or Tertiary deposits are found, they dip with the tilt of the block. Along the east side of the San Joaquin valley, several faults strike from the Sierra Nevada block out into the valley alluvium.

AREAS WEST OF VALLE GRANDE

Before the structure of the southern part of the Valle Grande is discussed, a brief outline will be given of some of the more striking geological details of the surrounding areas. Figure 1 gives the positions of the major positive blocks west and south of the San Joaquin valley part of the Valle Grande. These will be discussed briefly, beginning at the north.

Just south of Suisun Bay is the Altamont block. This seems to have been a barrier between the Valle Grande and the San Ramon basin during a large part of the Tertiary period; the fact that the Altamont block is composed mostly of Cretaceous rocks is evidence that it was covered during at least part of that time. At present, the eastern side of it is covered by the Mount Diablo thrust. Southwest of the Altamont block is the Mount Hamilton block, composed of Franciscan rocks and surrounded by faults. This great positive element evidently has existed as such since the beginning of Cretaceous time, though somewhat broken.

Southwest of the Mount Hamilton block and west of the San Joaquin valley are three blocks. The first of these is the Gabilan block, the

second the King City block, and the third will be referred to as the Parkfield block. It is possible that the south end of the Gabilan block should be recognized as a distinct unit. The areas west of these three blocks need not be considered at this time.

Gabilan block.—The Gabilan Mountains are a great rhombohedral horst composed of the old Coast Range granitic and metamorphic complex. On the north the lower Miocene deposits are folded against the metamorphics, along a primary fault. On the west are the Salinas fault and the Salinas valley, which here is a true graben having a major fault on either side; the alluvium and Pleistocene are the only deposits exposed on the surface of this area. A well is reported to have reached a depth of 900 feet in the Recent alluvium or possibly the Pleistocene. It is probable, however, that beneath the valley alluvium Miocene and Pliocene deposits will be found. The eastern side of the Gabilan block is defined by the San Andreas fault. The southern end of the block is formed in the angle where the Salinas fault crosses the north end of the King City block to join the San Andreas; here at the southeast end of the Gabilan Range and on the northeast side of the Salinas fault, between it and the San Andreas, is a small triangular area, previously mentioned as the possible fourth block, on which is a considerable thickness of middle and upper Miocene deposits. Whether or not this is a block distinct from the Gabilan is not known at present. No marine Pliocene beds are found on it, but more of the Miocene series is represented there than on the King City block farther south. Excepting this triangular area, there are no Cretaceous or Tertiary marine sediments on the Gabilan block. Along the east side of the main part of the block in the area known as the Pinnacles is a series of volcanic rocks, largely volcanic breccia. As Kerr and Schenck[1] have shown these rocks as the equivalent of similar beds associated with the lower Miocene deposits, they are tentatively referred to that period of time.

King City block.—South of the Gabilan Range is the King City block, the surface of which has been referred to as the King City Mesa. Here is a miniature Sierra Nevada block tilted toward the west against the King City fault, the upthrown side being along the San Andreas fault. The basement rock of the area is granite or metamorphic complex; this is overlain by a comparatively thin veneer of Santa Margarita (Upper Miocene) and Paso Robles (Pliocene) deposits. The dip of these beds corresponds with the tilt of the block. The block is more than 100

[1] P. F. Kerr and H. G. Schenck, "Active Thrust Faults in San Benito County, California," *Bull. Geol. Soc. Amer.*, Vol. 36 (1925), pp. 465-94.

miles long, with a maximum width of only about 15 miles near the north end, coming to a point along the east side of the Carrizo graben, where the King City fault joins the San Andreas fault zone. In the southern part of the block, north of the Carrizo Plains, there is some folding of the sediments, as shown by the mapping of W. A. English[1] for the area west of Parkfield.

Along the Salinas valley, where it follows the west side of the King City block, we do not find the typical graben such as is seen farther north; here the alluvium fill is on the lower side of the tilted block. West of the King City fault and on the west side of the Salinas valley is a thick series of marine lower, middle, and upper Miocene deposits, folded obliquely against the King City fault. The upper Miocene beds on this side of the fault are conformable with the middle Miocene (the Salinas shales), whereas on the east side of the fault they rest unconformably upon the granites.

Parkfield block.—East of the King City and Gabilan blocks is the long, narrow strip which has been referred to as the Parkfield block. This area has a maximum width of not more than 10 miles and a length of about 140 miles. In referring to it as a block, the writer realizes that the term "block" (and this applies to most of the larger blocks) is not strictly correct; it means that within this area we find the same general stratigraphic sequence, indicating that the rocks have acted as a unit. Thus, throughout the entire length of the so-called Parkfield block, the basement rock is of the Franciscan series, which is overlain by Miocene deposits. Near the south end, the upper Miocene deposits rest directly upon the Franciscan, but in most of the area Temblor deposits (middle Miocene) form the basal member of the Tertiary. Overlying the Miocene deposits along this narrow strip is a considerable thickness of marine Pliocene, including Jacalitos and Etchegoin, above which are the continental Tulare beds. In the vicinity of the Devil's Den region, the Parkfield block is lost in the folding of the Cretaceous along the margin of the Valle Grande.

West of the Parkfield block, the main part of the Gabilan block probably stood as an insular mass in the Miocene sea. It is also probable that a large part of the King City block was land during lower and middle Miocene, as is indicated by the absence of these deposits from most of that area. During the Pliocene period, the Gabilan and King City blocks and most of the area between the King City fault and the

[1] W. A. English, *U. S. Geol. Survey Bull. 691* (1918).

coast were land; the Pliocene sea came in across the Santa Cruz area, around the north of the Gabilan Range, and along the area of the Parkfield block, spreading out in the San Joaquin valley south of the Mount Hamilton block. This connection between the interior sea and the coast will be referred to as the San Benito trough.

East of the Parkfield block is the folded margin of the old Valle Grande. Here is found the great thickness of Cretaceous, Eocene, and Oligocene deposits which are not represented on the Parkfield block or in the general area on the west. As may be seen from the maps (Figs. 1 and 4) the folds along the margin of the Valle Grande are cut off obliquely against the Waltham Canyon fault zone, which defines the eastern side of the Parkfield block, whereas the folding on the Parkfield block is in general north and south.

AREA SURROUNDING THE SOUTHERN END OF THE SAN JOAQUIN VALLEY

The southern end of the San Joaquin valley is enclosed by a series of mountains which, seen from the valley side, form a broad arc joining the Sierra Nevadas to the Coast Ranges. This high mountain front, in places rather abrupt, is the north side of a complex knot of mountains. The greatest distance across these mountains, northeast and southwest, is about 70 miles, and the maximum width, at right angles, is 40 miles. The general elevation of the higher ridges is between 4,000 and 6,000 feet, and some are even higher.

From this Knot radiate several series of mountain ranges which, outside, are distinct units, but lose their identity in the Knot. On the west is one series, on the southeast is another, and on the northeast is the Sierra Nevada block.

The most eastern of the westward-radiating ranges are the Temblor Mountains, which bound the southwest side of the San Joaquin valley, and immediately west of them are the Caliente Mountains. These two ranges, the Temblor and the Caliente, are separated from each other by the structural valley, the Carrizo Plains.

The next major range south and west of the Caliente is that which forms the north side of the structural depression represented by the Cuyama valley. South of this is the San Rafael Range, a complex series of folded mountains bounded on the west by the Sisquoc fault and on the east by the Cuyama fault. Here we find a great thickness of Cretaceous, Eocene, and Miocene rocks. The deposits of the first two series are lacking in the areas adjacent on the west, and the lower Miocene

beds rest directly on the rocks of Franciscan age. Cretaceous deposits are found in the entire area between the Cuyama fault and the Carrizo Plains, south of the La Panza Mountains; Miocene sediments are around the margins, but it is doubtful if the whole area was covered at any time during that period. No marine Eocene, Oligocene, or Pliocene beds have been reported in the area.

South of the San Rafael Mountains, the next major range is that of the Santa Ynez Mountains, which, beginning on the coast, have an east-west trend and may be traced as a distinct unit for more than 50 miles eastward, losing their identity with the San Rafael Mountains in the Knot. The Santa Ynez Mountains, like the San Rafael, are composed of Cretaceous and Eocene rocks as well as later Tertiary deposits. These two ranges are separated west of their point of junction by the Purissima block, throughout a large part of which the Miocene sediments rest directly upon the Franciscan series (Jurassic). In this area is a series of minor ranges that are associated with primary faults.

Southeast of the Knot and bordering the San Andreas fault is the second series of great block mountains. These fault blocks, apparently great wedges of the granite and basal complex, separated the area of marine Mesozoic and Tertiary deposits on the west from that part of the Great Basin known as the Mojave Desert, in which only continental Tertiary deposits are found. To this great series of blocks southeast of the Knot belong the San Jacinto, San Bernardino, and San Gabriel ranges, and still farther north in the vicinity of the Knot are the blocks to which we will refer as the Elizabeth Lake block and the Pine Mountain block.

THE KNOT

The mountain mass, the Knot, consists of a series of fault blocks and is cut by some of the principal primary faults of the Pacific coast. Geologically this area is very complex. It may be divided into two distinct parts, (1) that which is underlain by the granitic complex and on which only continental deposits, tuff, and lava are found, and (2) the area in which are marine deposits.

Granitic area.—The granitic area is composed of a series of fault blocks, which stand at elevations ranging from 4,000 to 6,000 feet and in general have risen together, though there are differences in elevation of the different blocks. The San Andreas fault zone cuts through this area. The blocks west of the fault are in line with the large block mountain masses on the south, such as the Elizabeth Lake block and the San Gabriel Mountains, and they are separated from each other by compara-

tively low passes or depressions; each stands by itself. These depressions north of the San Gabriel Mountains were areas of sedimentation during the Tertiary, and marine waters during the lower Eocene and upper Miocene surrounded, at least partly, the Elizabeth Lake block. There seems to be no evidence that these marine deposits extended toward the east beyond the San Andreas fault into the Mojave Desert valley.

East of the San Andreas fault, in the granitic part of the Knot, is another series of distinct blocks, which have a northeast-southwest trend, joining the first series at an acute angle. They include the area generally referred to as the Tehachapi Mountains and a part of the San Emigdeo Mountains. Here are several structural depressions which have been formed by faulting and in which are folded Tertiary continental deposits, as well as lavas and tuffs. The Tehachapi part of this area has been very well described by A. C. Lawson.[1] The faults shown on the map (Fig. 1) are taken in part from Lawson's paper and in part from other sources.

These blocks, which connect the Sierra Nevadas with the Coast Ranges, may be thought of as a complex horst separating the San Joaquin valley from the Antelope valley. The southern side of this great uplift is bounded in part by the Garlock fault, and in part by the Antelope fault, which is parallel with it, the two faults being separated by the long, narrow Tehachapi Mountains block. The northern side of this part of the Knot is bounded by a zone of faulting against which the marine Tertiary deposits of the old San Joaquin basin have been folded.

The junction of these two series of block mountains in the granitic part of the Knot occurs along the San Andreas fault. Between it and the Antelope fault, which joins it in the granitic area, is the great wedge-shaped Antelope valley, a part of the Mojave Desert. This is an area of low relief. The mountains rise abruptly from the fault zones on the north and southwest. L. F. Noble,[1] in his paper on the San Andreas fault, has pointed out that the area south of the Garlock and Antelope faults, including the Mojave Desert and Antelope valley, has been stable for a long time, whereas north of this is a very unstable area, one that has been much dissected by thrusting and normal faulting of a comparatively recent date.

One of the principal conclusions from the study of this general granitic area of the Knot is that all the granitic blocks east and west of

[1] A. C. Lawson, "Geomorphology of the Tehachapi Valley System," *Univ. Calif. Pub., Bull. Dept. Geol.*, Vol. 4, No. 19 (1906), pp. 431-62.

[2] L. F. Noble, *Carnegie Inst. of Wash. Year Book*, No. 25 (1925-26), p. 420.

the San Andreas fault have been positive throughout Cretaceous and Tertiary times. This is also true of the great Sierra Nevada block on the north and of the major granitic mountain blocks on the south. The Cretaceous and Tertiary seas went up to, but did not cross, these blocks. They formed the outer margin of the great wedge-shaped area, the Antelope valley and Mojave Desert, where, excepting the sediments deposited by two inundations along the rift zones already mentioned, only Ceneozoic continental deposits were formed after the Jurassic period.

Area of marine sedimentation.—The part of the Knot in which marine sediments are found is southwest of the San Andreas fault, where such major ranges as the Santa Ynez and San Rafael mountains lose their identity, forming a complex mountain mass that is almost inaccessible. Great thicknesses of Cretaceous, Eocene, and Miocene sediments, which for the most part are of marine origin, are found in this general region. The area is much dissected by faulting, some of the great primary faults on the east coming close together or joining here. Evidently some of these faults, which are well defined on the south and the northwest, disappear in the folded sediments of this area, in much the same way as do certain faults in the San Joaquin valley. Very little detailed geological mapping has been done here because of the relative inaccessibility of the area.

WESTERN BORDER AREA

The border areas, as that term is here used, are those marginal areas around the Great Valley in which the deposits of the Valle Grande are exposed as the result of folding and faulting. The folds along the valley sides almost invariably plunge toward and disappear under the alluvium of the valley floor. The folding of the basin was evidently confined very largely to its margins. There is probably little folding under the middle of the present valley floor, as is indicated by the fact that the marginal folds of the border flatten out and disappear beneath the valley alluvium. What folding there is under the alluvium will, in the writer's opinion, be found to border the faults which extend out into that area.

SAN ANDREAS FAULT

In the discussion of the western border area the major structural units, from south to north, will be considered. The southwest side of the San Joaquin valley is bounded by the Temblor Range, which, as a distinct unit, has a length of about 60 miles. The west side of the range is defined by the San Andreas fault zone, which in this region is ordi-

narily several miles wide. Along this fault zone is a series of elongate sliver-blocks, each being composed of one or more of the formations found in the section on either side.

The San Andreas fault has generally been referred to as a single zone of faulting, but a study of the existing geological maps shows that this is not strictly true; in fact, it is composed of a series of faults, which can be traced into it from the northwest and southeast, each joining it *en échelon* and forming the zone for a short distance. Figure 2 shows a small part of the San Andreas fault zone, commencing a little north of the town of Parkfield and continuing south to the San Emigdeo Mountains, a distance of approximately 100 miles. (See also Figure 1.) This, in the writer's opinion, is fairly typical of the fault zone along its entire length.

As shown on the north end of the map, the Salinas and San Andreas fault zones join at an acute angle. A southeastern extension of these

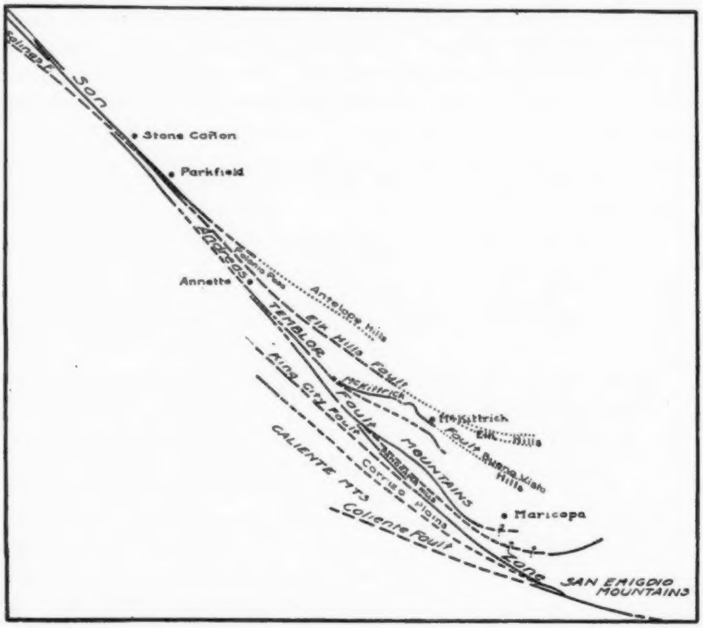

FIG. 2.—Details of San Andreas fault zone from Stone Cañon to the San Emigdeo Mountains, a distance of approximately 100 miles.

faults corresponds with the faulting in Polonio Pass, which zone of faulting, if projected toward the southeast, is in line with the Antelope Hills zone of folding out in the valley. However, another fault zone continues southward from the junction of the Salinas and San Andreas faults. It corresponds fairly well with the San Andreas fault zone north of the junction and might be considered as its continuation, but its southeastward projection takes it into the Elk Hills zone of folding, which is known to be associated with faulting.

On the south, and joining the Salinas fault west of its junction with the San Andreas, as already described, is another zone of faulting which must be considered a part of the San Andreas fault zone. This westernmost branch divides. The eastern of the two branches corresponds with and is a part of the McKittrick fault zone, which is on the west side of the northern part of the Temblor Mountains, and with the Buena Vista Hills zone of folding on the southeast, where well logs indicate strike-faulting along the entire line of structure. The western branch is taken as the San Andreas fault zone.

It is somewhat difficult to decide which of the several faults south of this is the main fault. Near the north end of the Carrizo Plains the fault zone splits into three branches. The eastern branch is found along the west side of the main part of the Temblor Range, the middle branch forms the east side of the Panorama Hills, and the western branch is on the west side of that short range and forms the eastern border of the Carrizo Plains.

The western of these three branches is considered the true San Andreas. It is joined at an acute angle on the northeast side of the Carrizo Plains by the King City fault, and south of the point of junction it is in direct line with the King City fault but not with the main zone on the north.

Within the narrow strips bounded by these three branches of the San Andreas fault are some very complicated structures which are the result of folding and faulting. In the eastern strip, granites are exposed unconformably overlain by lower Miocene sediments. The two eastern branches of the fault, traced toward the south, are lost in the Miocene sediments of the southern part of the Temblor Mountains; the complicated folding in those deposits suggests the possibility that the two zones, though lost on the surface, extend beneath the sediments and join the east-west zones of faulting found at the south end of the San Joaquin valley.

The San Andreas fault zone, as generally recognized, cuts across the San Emigdeo-Tehachapi Mountains southeast of the Temblor Mountains, where there is a decided curve in the trend; from here southeastward the fault does not correspond with the northern part, but with a zone of faulting on the south side of the Caliente Mountains. This relation of the Caliente zone of faulting to the San Andreas fault zone on the southeast might well raise the question of whether the name "San Andreas fault" should be applied to the zone of faulting in this southern area; the same question could be asked, however, of the so-called San Andreas fault along its entire length.

In summary, the San Andreas fault zone is formed of a series of distinct but closely related faults, which are a part of the general system that ramifies and cuts through the Coast Ranges. It is true that there is a continuous zone of faulting along the entire length of the San Andreas; an analysis of this, however, shows that different segments of the zone are in line with other primary faults, which join it, causing the main fault zone to be offset *en échelon* where the junctions take place. This characteristic of the San Andreas fault is found in many other major zones; it is especially true of the Haywards and Sunol faults, with the details of which the writer is familiar.

TEMBLOR MOUNTAINS

The Temblor Range is divisible, on the basis of structures and differences in geological sequence, into two distinct parts, a southern and a northern. The line of division between the two is at McKittrick fault, which extends into the Buena Vista Hills zone of folding (Fig. 3).

Southern part.—The Temblor Range south of the McKittrick fault is composed of Miocene and Pliocene deposits. The crest of this part has a general elevation of approximately 3,000 feet, and some of the higher points, of more than 4,000 feet. The western side is formed by the eastern branch of the San Andreas fault, previously mentioned.

The border area of the Valle Grande south of the McKittrick fault may be considered as beginning at the eastern branch of the San Andreas fault. Although the Miocene in the narrow strip between the two eastern branches rests upon the granite, yet east of this it is probable that the Cretaceous and older Tertiary deposits are buried beneath the Miocene and are not exposed because the folding has not been sufficient to bring them to the surface. West of the western branch of the San Andreas fault are the Carrizo Plains; in this area is a typical graben where, in certain wells, alluvium has been reported down to a depth of 2,000 feet.

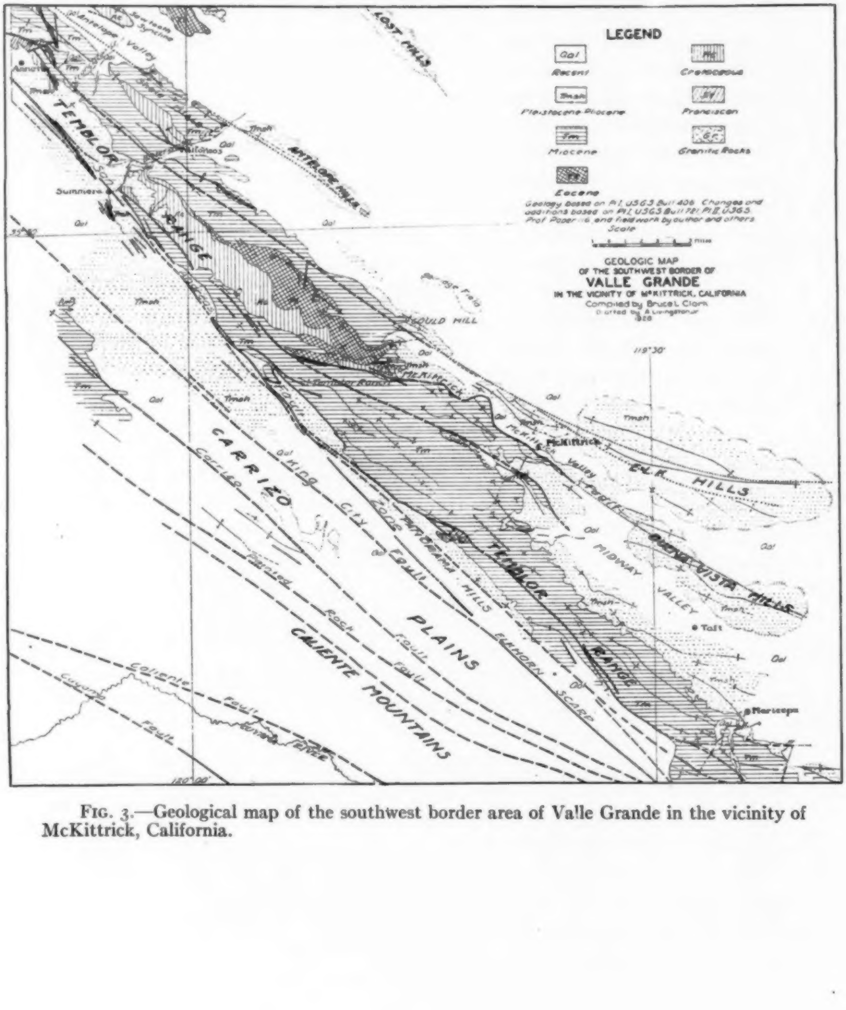

FIG. 3.—Geological map of the southwest border area of Valle Grande in the vicinity of McKittrick, California.

One of the distinctive characteristics of the Miocene, Pliocene, and Pleistocene deposits of the southern part of the Temblor Mountains is the presence in them of granitic conglomerates and arkosic sands, which evidently were derived directly from a granitic source. Pack[1] reports the presence of granitic conglomerates closely associated with the upper part of the Maricopa shales, and he shows an illustration of one boulder of granite 16 feet in diameter which was found embedded in the shales. It would appear that such boulders must have come from a source close at hand. Old terrace deposits, composed almost entirely of granitic boulders, are found on the top of the Temblor Mountains west of the towns of McKittrick and Taft, but as they thin and disappear toward the south, it is improbable that they were derived from the granites of the San Emigdeo Mountains.

There are three possible sources of these conglomerates. They may have come (1) from the granite of the San Emigdeo Mountains block which is about 20 miles distant on the south, (2) from insular masses that were slivers along the San Andreas fault, or (3) from a granitic mass which now underlies the alluvium of the Carrizo graben. To the writer it seems improbable that the Miocene and Pliocene granitic conglomerates came from the south because the shore lines of the Miocene and Pliocene seas were on the south side of the southern granitic masses. During Vaqueros and Temblor times marine sediments were laid across the northern border of the San Emigdeo block; the character of these deposits indicates a fairly low shore line, and this, together with the absence of Pleistocene conglomerates on the old surface near the southern end of the Temblor Mountains, would seem to preclude the possibility of their origin from that direction. The second possibility also seems rather improbable because of the small size of the present exposures of granite in that area. The Miocene and Pliocene deposits cover the entire strip between the western branch and the main San Andreas except in the small granitic areas previously mentioned. It seems improbable that these small masses of granite, unconformably overlain by Miocene deposits, could have produced sufficient débris to account for the Miocene and Pleistocene conglomerates.

In the writer's opinion the last possibility is most probable; that is, there was a high granitic insular mass rising where now is the Carrizo graben, and from this mass the granitic conglomerates and isolated boulders in the Miocene shales and Pleistocene terrace deposits were

[1] R. W. Pack, "The Sunset-Midway Oil Field, California," *U. S. Geol. Survey Prof. Paper 116* (1920), p. 30.

directly derived. During the Pleistocene the block was depressed and to-day we find the graben in its place.

The deposits of the southern part of the Temblor Mountains area are highly folded. A section a little north of the town of Maricopa crosses five anticlines, most of which are parallel with the range, but none of which extends through the entire length of this part of it. Associated with the folds are several short strike faults.

Northern part.—The northern part of the Temblor Range is distinguished from the southern by (1) the presence of older rocks, Jurassic and Cretaceous, on the surface, (2) a greater amount of faulting, so that the structures are more complicated, and (3) folding oblique to the valley and crossing the range from northwest to southeast, whereas in the southern part the folds are parallel, or nearly so, with the range. From the southern end of this northern division, as far north as Franciscan Creek, folding predominates over faulting. North of this is an area in which the structure is much more complicated because of faulting.

The largest general structure in this area south of Franciscan Creek will be referred to as the Temblor anticlinorium, which has a length of more than 20 miles and a maximum width of about 5 miles. Along almost the entire length of this complicated general fold is an elongate strip of Cretaceous rocks, overlying which on the southern and eastern sides is a considerable thickness of Eocene deposits that may be traced around the nose of the plunging fold onto the southwest side. The Eocene deposits are absent from most of the west side, where the Miocene beds rest directly on the Cretaceous. The structure is surrounded, except at the north end, by a great series of Miocene sediments, the Vaqueros formation and the Maricopa shales; it begins in the northwest at the San Andreas fault and disappears in the alluvium of the valley on the southeast. On the north the Cretaceous beds are covered by the continental McKittrick deposits (Pliocene-Pleistocene), but, if projected under this overlying mantle, they would be cut off by the San Andreas fault.

The southeastern end of the Temblor anticlinorium is highly folded; some of these short folds strike obliquely away from the axis of the main structure *en échelon*. In the northern end there appears to be only one fold, which is bounded on the west by the San Andreas fault zone; farther southeast it is bounded by the McKittrick zone of faulting that branches off from the San Andreas zone. The Temblor anticlinorium, disregarding the minor folding, may be considered a great *en échelon* fold formed against these zones of faulting. There is another fault south of the Temblor anticlinorium on the east side of the Santa Maria valley,

the Santa Maria fault; this, if projected, would join the McKittrick fault.

The highly folded southeastern end of the Temblor anticlinorium is also complicated by faulting, and some of the small folds seem to have been twisted toward the northeast and formed against these faults (Fig. 3). One can hardly doubt that the fault zone on the southwest side of the Temblor anticlinorium is an important major structural feature and that the folding in this area and farther southwest is closely related to it.

East and northeast of the Temblor anticlinorium is a series of folds, all of which have their origin in a faulted area on the northwest and strike southeastward into the alluvium of the valley. One of the larger folds, as seen just north of the Alfonzo ranch house, in which area Cretaceous rocks reach the surface, is faulted near its southern end. This faulting corresponds with a zone of faulting in Polonio Pass a few miles distant on the northwest.

Between Polonio Pass (Fig. 4) and Franciscan Creek (Fig. 3) is an area in which the geology is much more complicated than that already described. Here are several small fault blocks, on some of which are Franciscan and Cretaceous rocks, although on others only the Miocene deposits reach the surface. The individual blocks of this area have been folded independently. At Polonio Pass is one of the most conspicuous structural breaks of the west side of the San Joaquin valley; the Temblor Range ends here and immediately north is the southern end of the Parkfield block. As already stated, the faulting in the Polonio Pass area lines up with the zones of faulting at the southeast.

In the northern part of the Temblor Mountains there are at least two overlaps that are significant in reconstructing the history of the Valle Grande. The first is an overlap of the Miocene, which cuts out the Eocene deposits on the north and west sides of the Temblor anticlinorium; the second is the overlap of the McKittrick continental deposits (Pliocene-Pleistocene) across the beveled edges of all the older formations of the same structure (Fig. 4). In the northern part of the area the white shales, the upper Miocene part of the Maricopa formation, form a much larger part of the section than they do farther south; the lower middle Miocene shales thin out northward. It would appear that the upper Miocene overlap, which is found in the area of McLure Valley (Fig. 4) begins here. The Kreyenhagen shales (Oligocene), which are well represented in the section west of Polonio Pass (Fig. 4) in Wagon Wheel Mountain, do not seem to be present in any of the sections in the Temblor Mountains.

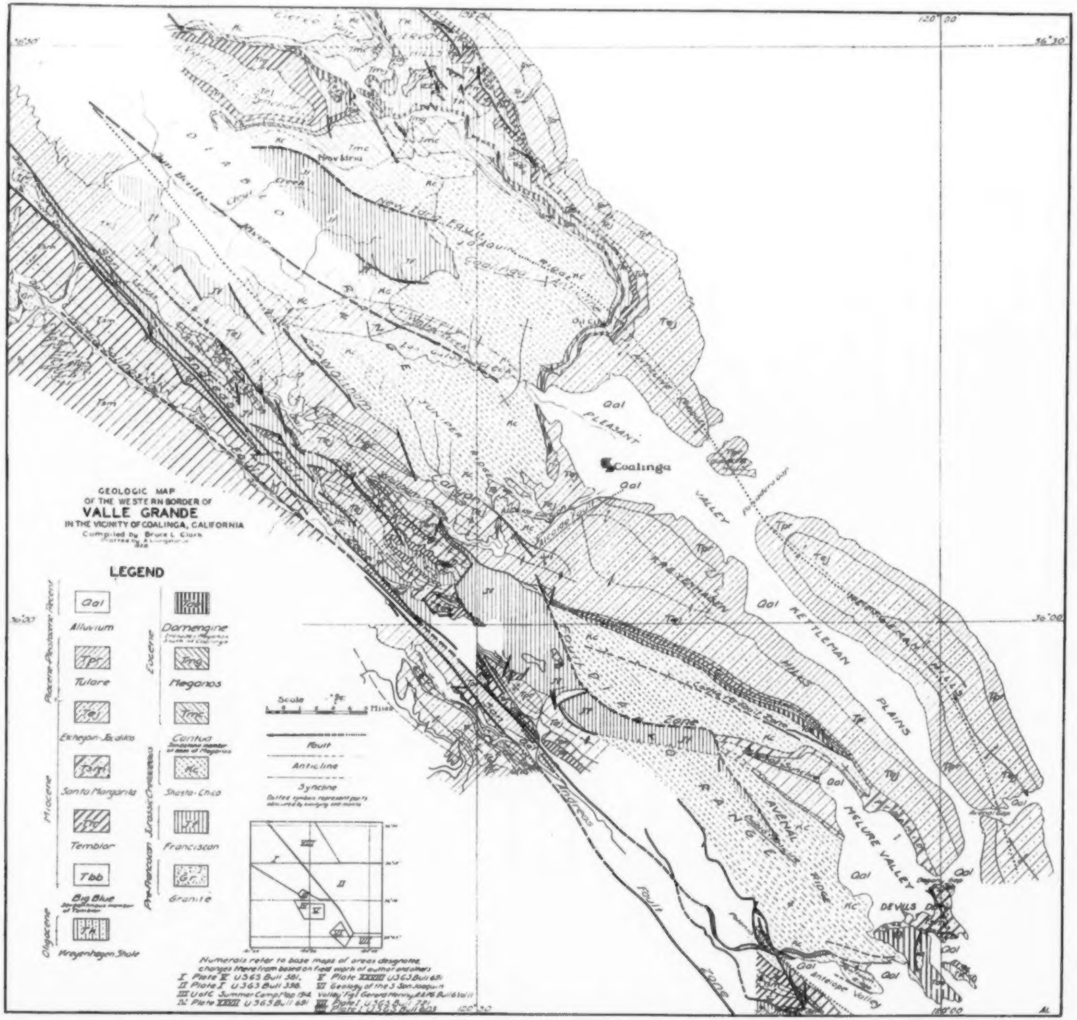

FIG. 4.—Geological map of the western border area of Valle Grande in the vicinity of Coalinga, California.

STRUCTURES IN SAN JOAQUIN VALLEY EAST OF TEMBLOR MOUNTAINS

Before considering the major structural features north of Polonio Pass, attention should be called to some of those in the valley east of the Temblor Range. In this area are three major zones of folding which branch off, *en échelon*, from the Temblor Mountains; between these are several minor zones. Along each of the major zones of folding is a series of anticlinal hills, so recent in origin that in some places well-preserved erosion surfaces may be seen nearly paralleling the dip of the beds on either side of the folds, and it is very possible that the folding which arched these surfaces is still active. The three major lines of folding will be referred to by the names of the hills that resulted. The southernmost is the Buena Vista Hills zone; just northeast of it is the Elk Hills zone; and north of this is the Antelope Hills zone. Some of the principal oil fields of California are on these structures.

The fold of the Buena Vista Hills zone, as seen just southwest of the town of McKittrick, is broken along a thrust that dips toward the south. This part of the McKittrick fault was described in a recent paper by Walter A. English.[1] Similar faulting has been reported in the records of some wells on the same line of folding but several miles farther southeast. As already stated, the McKittrick fault bounds the southwest side of the Temblor anticlinorium. Thus, the folding of the Buena Vista Hills zone was produced along the McKittrick fault zone; therefore, it is closely related to that of the Temblor anticlinorium.

An interesting fact, brought out by a study of the exposed sections on the two sides of the McKittrick fault, is that the continental McKittrick deposits (Paso Robles of Pack[2]) on the south side of the fault have a considerable thickness and are involved in the folding, whereas on the north side they are thin and lie horizontally or at a low dip. This sudden change in the thickness of the beds is undoubtedly the result of faulting that produced an irregular floor during the deposition of the McKittrick sediments; the block on the north side of the fault was positive, while that on the south was negative and was receiving a greater amount of sediment. It is probable that this fault was in existence throughout the Tertiary, judging from our knowledge of similar faults, found farther north on the west side of the Valle Grande, some of which can be proved of pre-Miocene age; at least one and possibly all are of pre-Cretaceous age. These will be discussed later.

[1] W. A. English, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 11, No. 6 (1927), pp. 117-20.

[2] R. W. Pack, *op. cit.*

The folding of the Elk Hills zone is broader and more complex than that of the Buena Vista Hills zone. Recent detailed work shows that it is associated with strike faulting, which accounts for some of the peculiar types of folds developed there. It corresponds with a zone of faulting in the immediate vicinity of Polonio Pass; this is taken as evidence that it, like the folding of the Buena Vista Hills, was produced along a northwest-southeast zone of faulting, which branches off from the San Andreas fault but seems to have broken through to the surface along only a part of the line, being buried along the rest.

The third of the major structures out in the valley, the Antelope Hills zone of folding, is very little known except from well logs. The North Belridge oil field is on this structure. The surface uplift has not been sufficient to expose the older rocks beneath the alluvium, but the alluvium is distinctly arched, showing very recent folding. This leads into an area on the northwest where the Miocene rocks are exposed in a general zone of folding, thence into the faulted area of the Polonio Pass region.

To sum up, all the folding developed in the Temblor Mountains and in the area adjacent on the east is closely associated with faulting. The main range itself was uplifted on the west along the San Andreas fault zone. The folding in the southern part of the range is nearly parallel with the main axis of the range, and the folds are associated with a number of discontinuous strike faults. In the northern part of the range the folding strikes obliquely across the range, and all the larger folds, if projected toward the northwest, line up with zones of faulting which are closely related to the San Andreas rift. Especially noteworthy is the faulting found along the Buena Vista Hills and Elk Hills structures.

BORDER AREA BETWEEN POLONIO PASS AND MOUNT HAMILTON BLOCK

The border area lying between Polonio Pass and the Mount Hamilton block is separated from the Parkfield block by the Waltham Canyon fault, which, as mapped by Pack and English,[1] is more or less of a discontinuous zone (Fig. 4). Probably in some localities the fault is mantled by the Pliocene deposits, not breaking through to the surface. However, there is undoubtedly a continuous zone of faulting in the deposits below the latest Tertiary covering, as is indicated by the fact that all along this narrow area from Table Mountain, which is just south of the town of Parkfield, as far north as the northern end of the

[1] R. W. Pack and W. A. English, "Geology and Oil Prospects in Waltham, Priest, Bitterwater, and Peachtree Valleys, California," *U. S. Geol. Survey Bull. 381* (1914), pp. 119-60, and map.

Gabilan Range, Miocene deposits are found resting unconformably upon the Franciscan; and the Cretaceous, Eocene, and Oligocene deposits, which have a thickness as great as 25,000 feet just east of the Waltham Canyon fault, are entirely absent on the Parkfield block. Also, this great thickness of Cretaceous and lower Tertiary deposits is cut off abruptly at the Waltham Canyon fault, and the lithology of much of the sediments indicates that they were derived from the area adjacent on the west.

The most conspicuous structural feature of this part of the border area is the *en échelon* folds, which have their origin near the major zone of faulting on the west side of the area. They are broken in their northern end by strike faults that do not extend their entire length, but disappear in the folds at the southeast.

It is significant in connection with these folds that the younger deposits in the synclines are very close to the western zone of faulting, in some places being cut off by it, and the greatest thickness of Cretaceous deposits exposed in the border area is ordinarily found in the middle of the anticlines. These facts show conclusively that the deposits of this part of the border area have been folded against the western positive masses along the fault zone, and that the fault zone is older than the folding.

Sawtooth syncline and Diablo anticline.—In the vicinity of Polonio Pass are two of these northwest-southeast *en échelon* folds. The first, a syncline, beginning at the south, is just north of Antelope valley; this is indicated on the maps as the Sawtooth syncline. It seems to originate in a zone of faulting, which bounds the south side of Avenal Ridge, and plunges out into the alluvium of the valley on the southeast. Several thousand feet of coarse arkosic Eocene sandstones are exposed in this fold. There is some faulting in the syncline, and between it and the next syncline at the north there is no corresponding anticline. The Diablo anticline includes the larger part of Avenal Ridge north of Cottonwood Creek; near its southern end it turns abruptly toward the southeast and also disappears in the alluvium of the valley. The southern part of this fold is in Cretaceous rocks; if traced northwestward, it is found to be faulted on the east side, with a core of Franciscan bordering the fault and the overlying Cretaceous deposits on the west side dipping into the San Andreas fault zone. These Cretaceous deposits on the west of the broken part of the anticline wedge out toward the north in a comparatively short distance along the San Andreas fault zone. This fault, which breaks the upper end of the Diablo anticline but disappears in the

fold on the southeast, is the southern extension of one branch of the Waltham Canyon fault zone.

At its northern end the faulted Diablo anticline is cut off abruptly by an east-west fault. Here a large mass of Cretaceous shales has been faulted down into the serpentines of the Franciscan. English[1] interpreted the serpentines as being intruded into the Cretaceous shales. Later work has shown that this relation is due to faulting; in the writer's opinion there is no reason to doubt that the serpentines are older than the Cretaceous. In the area just north of where the Cretaceous is faulted down into the Franciscan the upper Miocene deposits rest unconformably on the Franciscan. This may be considered the southern end of the Parkfield block.

Pyramid Hills anticline.—The next large anticline at the north is the Pyramid Hills anticline. It is a much larger structure than the one already described; its northern flank has a length of a little more than 40 miles; the southern flank, approximately 25 miles. The fold disappears toward the southeast in the alluvium of the valley. In the center of the fold is a large wedge-shaped area of Cretaceous deposits; on the north flank is a considerable thickness of Eocene, Oligocene, Miocene, and Pliocene sediments. The older Tertiary deposits on the north side, if traced toward the southwest, are found to be successively overlapped by the upper Miocene shales of the Santa Margarita formation. This overlap begins near the nose of the anticline; first the lower Miocene beds disappear, then the Oligocene, and then the Eocene beds, bringing the upper Miocene shale down onto the Cretaceous. This last sequence is found on both sides of the Avenal syncline.

The upper Miocene deposits on the north flank of the Pyramid Hills anticline toward the northwest are cut off at the Waltham Canyon fault and strike into the Franciscan rocks of the Parkfield block; the Miocene deposits in the Avenal syncline are likewise cut off at the same fault zone, the Cretaceous deposits not extending around the nose of the syncline. Thus, the Cretaceous beds in the middle of the Pyramid Hills anticline do not connect on the surface with the areas of Cretaceous on the north and south. The western end of the Pyramid Hills anticline is broken by a zone of faulting, named by Arnold and Johnson the Castle Mountain fault zone, which probably has its origin at the Waltham Canyon fault on the west and disappears in the folds on the

[1] W. A. English, "Geology and Oil Prospects of the Salinas Valley-Parkfield Area, California," *U. S. Geol. Survey Bull. 691* (1918), p. 226, and map.

southeast. This appears to be the main southern continuation of the Waltham Canyon fault zone.[1]

Alcalde fault.—North of the Pyramid Hills anticline the next large fold is the Coalinga anticline; between the two, however, is a break, shown by the fact that the Miocene and older Tertiary deposits do not connect directly from one area to the other, but, as seen on the surface, are offset along an east-west line close to Alcalde Creek. This offset indicates a zone of faulting, which is buried throughout most of its length beneath the Pliocene. The Jacalitos and Etchegoin formations, which, south of Alcalde Canyon, rest conformably upon the Miocene, on the north side rest unconformably upon the Cretaceous; the change takes place abruptly and can be explained only as the result of faulting. This buried zone of faulting is called the Alcalde fault. There are two possible explanations of this offset and Pliocene overlap. The first is that it took place at the end of the deposition of the Miocene and before the deposition of the Pliocene sediments; this would imply pre-Pliocene folding and a considerable lateral offset on the Alcalde fault, of which there is no evidence. For example, there is no large structural unconformity between the Pliocene and Miocene deposits either north or south of the fault such as would undoubtedly exist if there had been any great amount of pre-Pliocene-post-Miocene folding and faulting. The second possibility is that the Alcalde fault represents an old zone of faulting, north of which in pre-Miocene time the Cretaceous and Franciscan had been brought to the surface by movements along it and the Waltham Canyon fault.

The overlap of the upper Miocene deposits on the south shows conclusively that folding was taking place on the Pyramid Hills anticline in pre-upper Miocene time. This was also true of the areas of the Coalinga anticline, and it was probably true of all the major folds of the border area. During the Miocene there seems to have been an insular mass north of the Alcalde fault. The north side of this insular mass was defined by the New Idrea fault, which was active; folding was taking place on the Coalinga anticline throughout the Tertiary, as is indicated by the various unconformities in that area. According to this hypothesis, during the middle Miocene the insular mass was composed of Cretaceous and Franciscan; its southern shore line was on or near the Alcalde fault and

[1] Since this paper went to press R. D. Reed has informed the writer that mapping, done under his direction in this area, shows that the Castle Mountain fault is in direct line with the Waltham Canyon fault, and that the northwestern part of the former is not correctly shown on the map. He reports finding Franciscan serpentines along this zone for a considerable distance. It is to be hoped that in the near future Dr. Reed will publish more details of the geology of this area.

the northern shore line was along the New Idrea fault. The Pliocene sea covered a large part of this area, as shown by the patches of marine Pliocene on the Cretaceous. The Alcalde fault, however, was still active, for the Pliocene deposits are at least three times as thick in the section immediately south of the line as in that on the north. This abrupt change in thickness was first pointed out by J. O. Nomland,[1] who suggested that it was due to faulting. The complicated folding of the region was the result of compression produced not only along the main western fault zone, that is, the Waltham Canyon fault, but also along the other faults, including the Alcalde and the New Idrea. It seems that the folding south of the Alcalde fault, for example, the Jacalitos anticline, is closely related to that fault.

Coalinga anticline.—The Coalinga anticline begins on the northwest between the San Benito and New Idrea faults. Rocks of Franciscan age form the core near the upper end of the plunging fold. Recent detailed work by William Barbat and William Rand[2] shows that the New Idrea fault, of which only a small part was mapped by Anderson and Pack,[3] is well developed all along the north side of the Franciscan area, disappearing toward the southeast in the folded Cretaceous of the anticline; it can be traced northwestward for about 20 miles, where it seems to join the Waltham Canyon fault zone. According to Rand and Barbat the fault is well exposed in the workings of the old New Idrea Quicksilver mine, where it dips east at a fairly high angle. On the north side of the fault the Cretaceous deposits, which form a part of the south side of the Vallecitos syncline, thin out against the New Idrea fault so that much of the lower part of the Cretaceous of this section, the Panoche formation, which has a thickness of several thousand feet near the nose of the anticline, is cut out and only a part of the Moreno shales (Upper Cretaceous) is exposed, the Panoche and Knoxville formations not having been brought to the surface.

The Tertiary deposits, including the Eocene, Oligocene, Miocene, and Pliocene, of the Vallecitos syncline may be traced from the vicinity of the edge of the San Joaquin valley toward the northwest for a distance of about 30 miles into the border area. The syncline, however, does not extend out into the valley; at its north end the beds strike

[1] J. O. Nomland, "The Etchegoin Pliocene of Middle California," *Univ. Calif. Pub., Bull. Dept. Geol.*, Vol. 10 (1917), No. 14, pp. 203-04.

[2] William Barbat and William Rand, unpublished report.

[3] Robert Anderson and R. W. Pack, *U. S. Geol. Survey Bull. 603* (1915).

into the Franciscan rocks of the southern end of the Mount Hamilton block, from which they are separated by a fault. The relation of the areal distribution of the Cretaceous deposits to the New Idrea and Waltham Canyon faults shows that the non-appearance of the Cretaceous beds on the surface is not due to their having been dropped down along these faults, but that they were folded against them. There is no reason to believe that they have ever been exposed, except possibly at or near the time of deposition. This is a situation similar to that described in connection with the Diablo anticline and the Pyramid Hills anticline, the Tertiary sediments in the syncline striking into the western zone of faulting, and the Cretaceous, exposed in the anticline, being isolated from the Cretaceous areas on both south and north.

The Coalinga anticline plunges toward the southeast and disappears in the depression between Pleasant Valley and the San Joaquin valley. Immediately south of this, however, and in direct line with it, is a zone of folding which may be traced for a distance of about 50 miles. The Lost Hills field is near the south end of this zone, whereas the Kettleman Hills form the middle and southern parts. The general zone of folding, including the Coalinga anticline, has a length of about 75 miles. So far as the writer is aware, this is the largest continuous zone of folding in the Coast Ranges of California. There is evidence that it was brought about by compression along a zone of faulting that is buried under the later sedimentary shell throughout most of the area. The New Idrea fault is probably a part of that zone, and possibly the fault on the southwest side of the Franciscan mass in the Coalinga anticline also joins it; the faulting, which has been recorded from the well logs of the Lost Hills area on the west side of the Lost Hills anticline, shows that this buried fault extends at least that far south. That the unbroken folded deposits, as seen on the surface of the Kettleman Hills, are underlain by faulting is suggested by the complexity of the folding. According to G. C. Gester, recent mapping by the geologists of the Standard Oil Company of California shows that the Kettleman Hills do not represent one continuous anticline (Arnold and Anderson's concept as shown on their map in *U. S. Geol. Survey Bull. 398*), but that there are several oblique or *en échelon* folds such as would be found along a zone of faulting. Very recently a new oil field has been discovered by the Millham Exploring Company on the top of one of these folds.

Ciervo anticline.—The last major *en échelon* fold, northward along this part of the western border area, is the Ciervo anticline, which is just southeast of the Mount Hamilton block. The nose of the fold plunges

southeast and disappears on the northeast side of the nose of the Coalinga anticline; thus, neither the Ciervo anticline nor the Vallecitos syncline reaches the valley, but each merges toward the southeast with the Coalinga anticline. The Cretaceous and Tertiary deposits that form the border area on the north along the east side of the Mount Hamilton block, from which they dip toward the valley monoclinally, also form the north flank of the Ciervo anticline. The east and south sides of the Mount Hamilton block are defined by faulting, as may be seen on the map. These faults meet in the Cretaceous of the northern end of the Ciervo anticline; on the southeast, however, the fold is unbroken and the fault disappears in the fold.

MECHANICS OF FOLDING ILLUSTRATED BY THE NEW IDREA FAULT

Reference has already been made to the evidence for the pre-Miocene age of the Alcalde fault (Fig. 4), and it has been suggested that the New Idrea fault was active at the same time. In the writer's opinion this fault is typical of the faults that radiate into the valley from the zone of faulting of the western border area, and it is also one of the best illustrations of folding by drag. In the area are found good illustrations of the conditions of deposition on the west side of the Valle Grande, together with the conditions of sedimentation in that basin.

Big Blue.—One of the most distinctive lithologic members in the Tertiary deposits, as exposed on the north flank of the Coalinga anticline, is locally known as the Big Blue. These beds overlie the Temblor marine deposits, but they are continental in origin and have yielded a vertebrate fauna, which was described by J. C. Merriam[1] as the fauna of the *Merychippus* zone. On the south side of the Coalinga anticline the Big Blue member is inconspicuous, but around the nose of the fold on the north side the formation is thicker, and just east of the area of the serpentine rocks of the Franciscan, which crop out in the center of the Coalinga anticline, Anderson and Pack have shown it as a mappable unit for about 3½ miles (Fig. 4). In this small area a large part of the Big Blue is composed of serpentine débris. Angular serpentine boulders 30 feet in diameter are surrounded by a fine, powdery serpentine matrix. The best locality in which to see the Big Blue, as here described, is just south of Cantua Creek.

The only possible explanation of the Big Blue seems to be that it was derived directly from a serpentine mass as a slide from a fairly great

[1] J. C. Merriam, "Tertiary Vertebrate Faunas of the North Coalinga Region of California," *Trans. Amer. Phil. Soc.*, n. s., Vol. 22 (1915), pp. 4-26, pl. 3.

elevation, and it is probable that the slide came from the serpentine which crops out due east and in the center of the Coalinga anticline. If this is so, these serpentines must have been exposed as the result of movements along the New Idrea fault. It should be remembered that the main folding of the anticline, as we now find it, took place near the

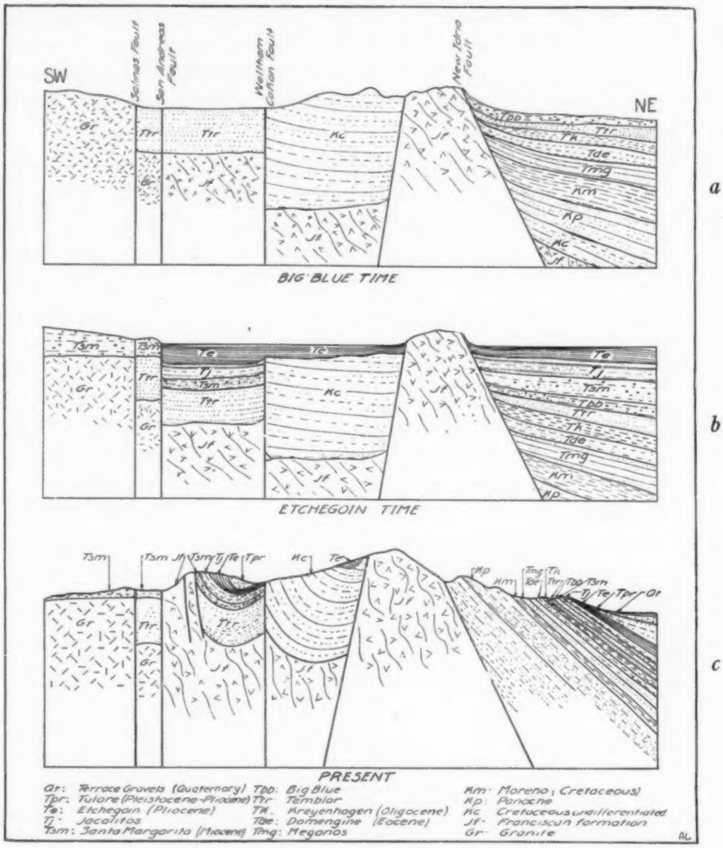

FIG. 5.—Diagrammatic cross sections of the New Idrea fault. *a* shows the probable conditions during the deposition of the Big Blue; *b* shows the probable conditions during Etchegoin (middle Pliocene) time; *c* shows the section as it exists to-day after the folding.

end of Pliocene and during Pleistocene times. The diagrams in Figure 5 illustrate the writer's concept of the manner in which these deposits were formed against the New Idrea fault and afterward folded. Diagram *a* illustrates the condition at the end of the deposition of the Big Blue, *b*, the condition after the deposition of the Etchegoin, and *c*, the final result of the folding when the deposits, which had been laid down against the fault and buried by the later sediments, were exposed as the result of compression produced by the dragging forces along the fault. These sections show the uneven floor of deposition along the western margin of the Valle Grande, and the manner in which the different blocks were folded independently.

BORDER AREA OF MOUNT HAMILTON BLOCK

The border area north of the Ciervo anticline is, in general, more simple in its structural features than that on the south; as far as the north end of the Mount Hamilton block the Cretaceous and Tertiary deposits dip monoclinally toward the east away from the Franciscan; near the north end complications appear as the result of thrusting. The Mount Diablo thrust has been found as far south as Puerto Canyon (Fig. 1); how much farther south is not known.

The Cretaceous deposits on the west side of the border area are in fault relationship with the Franciscan of the Mount Hamilton block. This zone of faulting was first shown on the fault map edited by Bailey Willis and published by the Seismological Society of America. Only the southern end of the zone was recognized in the mapping of Anderson and Pack.[1] The writer was able to study the Franciscan Cretaceous at two localities, one on Quinto Creek (Fig. 1) and the other on Puerto Creek. The fault zone was well developed at both localities. The old age of the faulting is indicated by the great thickness of Cretaceous conglomerates. In the lower part of the Cretaceous section on Quinto Creek are approximately 5,000 feet of conglomerates and sands with a minor amount of shale, the conglomerates forming the larger part of the series. The conglomerates contain boulders derived from the Franciscan, including chert and Franciscan igneous rocks of several types; with them are granitic and metamorphic rocks that can be matched with those of the Gabilan Mountains. A similar conglomerate is found above the Mount Diablo thrust on Puerto Creek.

[1]Robert Anderson and Robert Pack, "Geology and Oil Resources of the West Border of the San Juan Valley North of Coalinga," *U. S. Geol. Survey Bull. 603* (1915). See geological map.

Anderson and Pack,[1] in discussing the conglomerates of the Cretaceous of this area, make the following statement:

> The great bulk of the pebbles are of a type of rock different from those now exposed in the center of the Diablo Range, and the location of the land mass from which they were derived is problematic. Between Little Panoche and San Luis creeks a very few of the larger and less rounded fragments are somewhat similar to the various igneous rocks exposed in the upper portion of the Franciscan formation in that vicinity and may possibly have been derived from it. In general, however, the lack of pebbles, plainly indicating a derivation from the Franciscan rocks, is a noteworthy feature of this formation.

The writer was therefore much surprised to find Franciscan boulders very plentiful in the Cretaceous conglomerates on the east side of the Mount Hamilton Range. On Quinto Creek, which is only a little north of the section discussed by Anderson and Pack, there are Franciscan boulders in the conglomerates at various horizons from the base well up to the top of the Panoche formation and in the basal Marino. In order to be certain of his conclusions, the writer, not being a petrographer, invited Karl Rode of the University of Bonn, Germany, who at that time was doing graduate work at the University of California, to accompany him on several trips. The Gabilan Mountains, which are west of the Mount Hamilton Range, were visited and rock specimens were collected from the Basal Complex series of that region, and later, rock specimens were collected from the Franciscan series of the Mount Hamilton Range. All of these were compared with the boulders in the Cretaceous conglomerates. It was found that the conglomerates were composed very largely of Franciscan rocks, other igneous rocks, and granitic boulders. A large part of the Mount Hamilton Range opposite the conglomerate localities studied is composed of igneous rock, and all the types of rocks found in the Franciscan here were found as boulders in the conglomerates. The granites of the southern Gabilan Range have a pink or reddish color and are very distinctive; specimens of this granite matched perfectly some of the boulders in the conglomerates.

This great thickness of conglomerates at Quinto Creek can not be traced any great distance north or south. They have the appearance of old delta deposits, derived from the land mass adjacent on the west and dumped into the basin of the Valle Grande across the western zone of faulting, where they accumulated against the face of the fault. Thus, the conditions of deposition on the west side of the Mount Hamilton block were similar to those on the south, where also there is a western zone of faulting, against which the deposits in the Valle Grande accu-

[1] *Op. cit.*

mulated, later to be brought to the surface by compression along the same zone. In the former region, however, the component of movements was not such as to produce *en échelon* folding as it did in the latter; the forces were more direct, the result being the monoclinal dip away from the fault.

BORDER AREA IN VICINITY OF MOUNT DIABLO

North of the Mount Hamilton block is the Altamont block. It was positive during the Tertiary and separated the San Ramon basin from the Valle Grande, but thrusting has pushed the deposits of the border area upon it, and at one locality completely across it. Thus, the major zone of faulting, which undoubtedly bounded the east side of the Altamont block, is buried under the Mount Diablo thrust. The details of this thrust, which is the largest known low-angled thrust in the Coast Ranges, are very complex and will be reserved for discussion in a later publication.

NORTHERN BORDER AREAS

In this paper the discussion of the details of the structural features of the Valle Grande is limited almost entirely to the southern part, for the reason that there is comparatively little published information pertaining to the northern part. In the main, the geological work that has been done north of San Francisco Bay is of a reconnaissance nature. One of the handicaps of the geologist in this northern area is the lack of topographic maps. The writer has seen enough of the area to convince him that the structural features are essentially the same as those in the southern part, that is, a zone of faulting along the western side of the Valle Grande, on the west of which were positive areas that existed during Cretaceous and Tertiary times. The presence of Franciscan rocks throughout the Coast Ranges north of San Francisco Bay shows that during that period the area was negative, but at the close of the Sierra Nevada revolution a large part of it became positive and has remained so. However, there was more than one general positive mass; evidently there was a series of large insular masses, between which were troughs or channels connecting the ocean with the interior basin during parts of Cretaceous and Tertiary times.

As one follows this general western zone of faulting, which separates the Franciscan series from the Cretaceous deposits, it becomes evident that the character of the basal Cretaceous beds changes radically, and that this change is not such as one would expect in going along a shore line. The only explanation, in the writer's opinion, is that given for the

western border area of the San Joaquin valley, that is, the Cretaceous beds were deposited against the general western zone of faulting and have been brought to the surface along the fault, the result being that one finds beds of different horizons striking into the Franciscan in going southward along the fault zone.

Another feature of the western border area of the Sacramento valley is the presence of faults which have a northwest-southeast trend and branch off from the western zone of faulting, disappearing in the alluvium of the valley. One of the best known of these faults is on the west side of the Capay valley (Fig. 1). It was described by David Durst.[1] This fault is active and some of the recent earthquake shocks felt in that region have been attributed to movements along it. The scarp formed along the fault is in soft Tertiary continental deposits; its recent origin is shown by the small amount of erosion. Later studies show that there is at least one other fault closely associated with the Capay valley fault. The valley itself is a small structural depression formed by faulting along its east side. Other faults, similar to those found in the vicinity of the Capay valley, are known but have not been mapped. No large *en échelon* folds, like those on the west side of the San Joaquin valley south of the Mount Hamilton block, have been reported, but future detailed mapping may show such structures, especially near the southern end, as in the area south of the towns of Williams and Woody.

Judging from what we know of the faults along the San Joaquin valley, it is possible that those in the western border area of the Sacramento valley may also exist out under the valley alluvium. It seems probable that certain low, rolling hills of the type which in southern California is referred to as a topographic "high," may be formed along such buried faults. A good example of this is the Dunnigan Hills (Fig. 1). Willis,[2] on his map, has shown a probable fault along this line of hills.

North of the Sacramento valley are the Siskiyou Mountains. Here, between the valley alluvium and the older pre-Cretaceous rocks that make up the Siskiyou Mountains, are considerable areas of gently-dipping marine Upper Cretaceous and continental Tertiary deposits. This seems to be what may be termed shelf deposition, or deposition across a positive block which has not been folded.

[1]David Durst, "Physiographic Features of Cash Creek in Yolo County," *Univ. Calif. Pub. in Geography*, Vol. 1 (1916), No. 8, pp. 331-72, pls. 37-44.

[2]Bailey Willis, Fault Map of California, *Seismological Society of America* (1922).

EASTERN BORDER AREA

On the eastern side of the Sacramento valley are found the same general conditions of deposition as those on the north. Properly speaking, there is no border area. Certain of the deposits, which were formed in the main basin, lapped upon the Sierra Nevada block, but nowhere in any great thickness. Neither do we find folding in these deposits; whatever dip they have is the result of the tilting of the Sierra Nevada block.

As in the northern area, only the Upper Cretaceous deposits (Chico formation) are found in this eastern area. Above them are marine Eocene sediments belonging to the Meganos horizon. The larger part of the Tertiary deposits are continental, and probably all the divisions of that period are represented in them. Associated with the continental deposits is a series of lava and tuff beds, most of which belong to the later Tertiary. Thus, on this side of the Sacramento valley, the alluvium comes up to, and laps upon, the Sierra Nevada block.

The east side of the San Joaquin valley, from the north end opposite the town of Stockton, southward approximately 100 miles, is bordered by the westward-tilted Sierra Nevada block, a large part of which is composed of granites that intruded and metamorphosed the Paleozoic and early Mesozoic deposits. The last granitic intrusion was of late Jurassic age. There is a comparatively thin veneer of unfolded Tertiary sediments on the western margin of the block and these are tilted with the block.

With one exception, these later Tertiary formations on the Sierra Nevada block are continental in origin. Evidently the only time when the marine waters lapped upon this part of the block was in the Eocene, and that was seemingly of short duration. Included in this superficial series is the Ione formation, the auriferous gravels, various lava flows and tuff members. It is not necessary for our purpose to discuss in detail the geology of this area. Lindgren[1] has given a very good résumé of the geology of the Sierra Nevada block.

A little south of the town of Porterville, the alluvium of the valley is separated from the tilted Sierra Nevada block by a series of low, rolling hills, composed, for the most part, of continental Pliocene and Pleistocene sediments, the Kern River formation. On the eastern margin of the area is a strip of lower and middle Miocene deposits; in the northern and middle parts the marine beds rest unconformably upon

[1] W. Lindgren, "The Auriferous Gravels of the Sierra Nevadas," *U. S. Geol. Survey Prof. Paper 73* (1911).

the granites of the tilted Sierra Nevada block, but in the vicinity of Kern River (Fig. 1) they are faulted down against the granites along the Kern River fault. This fault has been traced on the surface only a short distance toward the north; on the south it cuts back into the granites and lines up with the faulting on the north side of the Tehachapi valley.

North of Kern River is the Kern River oil field, the oil of which is found in a broad, monoclinal structure in the Kern River formation (Pliocene). Recent oil exploration north of this field has shown that the Kern River fault may be traced northwest of the river for a distance of more than 20 miles, beyond which it is covered on the surface by the later Pleistocene deposits. It seems probable that it extends at least as far north as the north end of the Pliocene-Pleistocene hills of this part of the border area. Recent aeroplane maps show that there are several faults paralleling the Kern River fault; apparently there is a fairly wide zone of faulting. Oil has been discovered recently at two new localities along this fault zone; these are locally known as the Round Mountain field and the Poso Creek field. Well logs seem to show that the oil accumulated in a monoclinal structure on the west side of the fault. No folding has been reported; the faulting seems to be normal.

Another zone of faulting recognized in the southern Sierra Nevadas is the Bear Mountain fault. Some geologists have believed that this extends under the alluvium toward the northwest and across the southwestern edge of the town of Bakersfield. This possible extension is shown in Figure 1, but is questioned, as is also the northern extension of the Tejon fault, which is the next fault on the south. The presence of a major zone of faulting, which can be traced from the Sierra Nevadas along the north side of the Tejon Hills, makes the northwestward extension of the first two faults, in the writer's opinion, questionable, because we find in the Coast Ranges few major faults crossing one another.

The part of the border area just discussed ends a few miles south of Kern River; it is cut off by a great embayment of alluvium, which extends back upon the granites of the Sierra Nevada block. South of this is the Tejon Hills area (Fig. 1). Here the lower Miocene deposits rest unconformably upon the granites. Unconformably above the Temblor (middle Miocene) is the Santa Margarita formation, and overlying it unconformably is the Chenac formation, probably in part equivalent to the Kern River formation in the area on the north. On the north side of this area is an east-west fault, south of which there is a broad, gently-

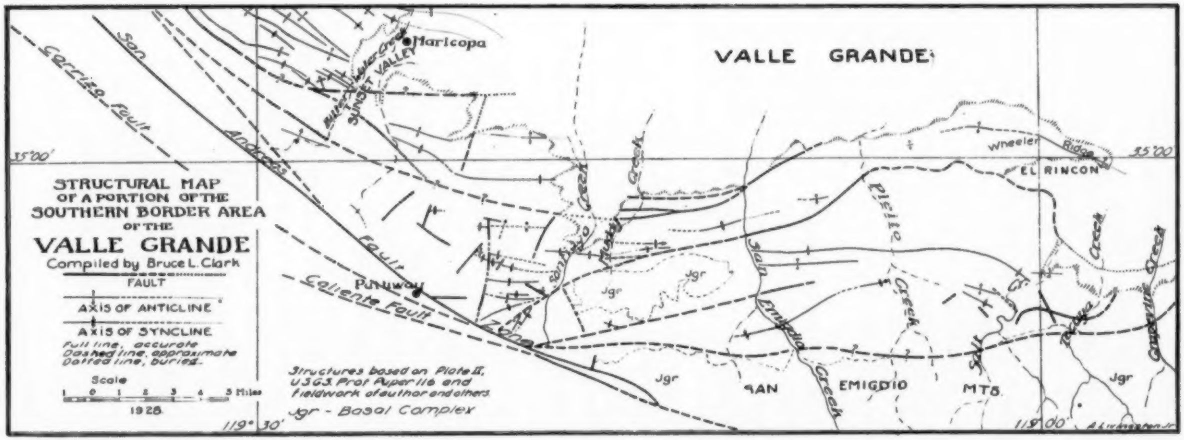

FIG. 6.—Structural map of a part of the southern border area of the Valle Grande, showing principal faults and folds west of Grapevine Canyon.

folded anticline plunging toward the west under the alluvium. It seems probable that the folding has a close relation to this fault.

SOUTHERN BORDER AREA

The geology in the southern border area, as shown in Figure 6, is very complex, so much so that seemingly no two men studying it have agreed as to the interpretation of all the structure. The latest publication on the area, covering, however, only as far east as Grapevine Canyon, is a paper by Robert Pack.[1] A part of the area has been remapped in more detail by Hoots of the United States Geological Survey and the results of his work will be published in the near future. It has also been mapped in detail by several oil companies.

There is a general zone of faulting north of the granitic part of the San Emigdeo Mountains, and the deposits are dissected by a series of discontinuous east-west faults. There are four belts of this faulting. The first comes in close to the granites. In places the Eocene beds are faulted down against the granites, as east of San Emigdeo Canyon; in other places, as in the vicinity of Tecuya Canyon, the granite is thrust upon the Eocene; and at still other localities the Eocene deposits rest unconformably upon the granite and the fault zone is either out in the Eocene formation or buried. Only a part of this southern zone of faulting is shown on Pack's map.

The second zone of faulting is east and west of San Emigdeo Canyon. The faulting is discontinuous and can be only approximately aligned. Near Tecuya Canyon, in the eastern part of the area mapped by Pack, is a short fault, only about 2½ miles in length, along which a narrow strip of granite has been brought to the surface, with Eocene beds on one side and Miocene on the other. This fault may be aligned approximately with an east-west zone of folding adjacent on the west, which in turn is in line with the east-west faulting in the vicinity of San Emigdeo Canyon and farther west. Evidently the folding and the fault on either side of it are very closely related.

The third zone of faulting may be seen on the east and west of Salt Creek, as a fairly low-angled thrust, but it is best developed in the area back of Wheeler Ridge, where the middle Miocene deposits have been pushed over onto the Pliocene. Here the fault has a dip of 30° or less, whereas only a short distance west, where it crosses San Emigdeo Canyon, it is nearly vertical. It may be traced across San Emigdeo Canyon and into the area on the southwest, where it seems to join the San Andreas fault zone.

[1]Robert Pack, *U. S. Geol. Survey Prof. Paper 116* (1920).

The fourth zone includes several short, seemingly discontinuous faults on the northern margin of the hills in and near the mouth of San Emigdeo Canyon.

In some parts of this southern border area the folding is very intense; the unconformities and overlaps, to be described later in the paper, indicate that crustal movements were active as early as Eocene time, and that most of the faulting antedates the folding.

The evidence for the early origin of the southern zones of faulting may be summarized as follows. Marine sediments seem never to have been deposited very far back on the granitic part of the San Emigdeo or Tehachapi areas, where only Tertiary continental deposits are found resting directly upon the granitic complex. The lithology of the marine Tertiaries on the north shows that they were derived from the granites; this was first pointed out by Robert Anderson.[1] The abrupt change in the sequence, as one passes from the southern border with its many thousands of feet of marine beds to the granitic area, a distance of only a few miles, where are the Tertiary land-laid deposits and volcanics, indicates that there was a straight shore line and that the granites were not folded up but were raised along a fault zone.

Thus, there appears to be good evidence that the southern boundary of the San Joaquin basin, even at a very early date, was defined by faulting, and that the deepening of the basin was produced by faulting rather than by folding, that is, the San Emigdeo and Tehachapi blocks on the south were not folded up but were faulted up.

OVERLAPS AND UNCONFORMITIES IN THE VALLE GRANDE AND THEIR SIGNIFICANCE

It has already been pointed out that there are several distinct overlaps in the formations along the border areas of the Valle Grande; some of the most conspicuous of these are in the southern border area. Overlapping conditions are found in the Eocene deposits at the south end of the San Joaquin valley. The Tejon formation of the type section, as seen at Grapevine Canyon, rests upon the granites, and on the west, beds of Domengine and Meganos age appear. This overlap is shown on the map compiled by Anderson and Hanna.[2]

Anderson and Hanna's map also shows an overlap from west to

[1]Robert Anderson, "Preliminary Report on the Geology and Possible Oil Resources of the South End of the San Joaquin Valley," *U. S. Geol. Survey Bull. 471* (1910), pp. 111-21.

[2]F. M. Anderson and G. D. Hanna, "The Tejon Eocene of the Type Locality in Kern County, California, *Calif. Acad. Sci. Occasional Papers*, No. 11 (1925), pl. 16.

east between the Vaqueros deposits and the Oligocene. In the western part of the area in the vicinity of San Emigdeo Creek, the marine Oligocene beds have a thickness of several thousand feet, whereas only a few miles east, near Salt Creek, they are entirely lacking and the Miocene deposits rest first upon the continental Tecuya beds (lower Miocene) and then upon the Eocene; still farther east, along the Sierra Nevada front, the Miocene deposits rest unconformably upon the granites. This overlap and unconformity was first described by Wagner and Schilling.[1]

Later, G. Henny[2] described an overlap at the base of the Vaqueros. Between Muddy Creek and San Diego Creek, where the Vaqueros rests with a marked structural unconformity upon the marine Oligocene deposits, the latter, according to Henny's interpretation, were isoclinally folded before the deposition of the Vaqueros, and only a short distance southwest the later beds rest unconformably upon the granites. Isolated erosional patches of Vaqueros were found back in the granitic area of the San Emigdeo Mountains.

Another overlap is found in this same general border area. It is that of the Etchegoin (Pliocene) across all the older formations. Henny,[3] in noting this overlap, says:

> The overlap of the Etchegoin is very apparent in this region. A broad syncline and an anticline in the Etchegoin and Paso Robles occur near the border of the San Joaquin Valley, apparently on a monoclinal series of older formations which dip very steeply. Here also the overlap of the Paso Robles on the Etchegoin is quite conspicuous.

A series of overlaps is found along the western border; some of them have already been discussed. Mention has been made of the overlap at the base of the Miocene as seen in the Temblor anticlinorium, and of the overlap of the continental deposits of the McKittrick formation (Pliocene-Pleistocene) across the northern end of that same structure and, north of that, on both sides of the San Andreas fault. The overlap that occurs at the base of the upper Miocene, as seen in and west of the Avenal syncline, has been described in considerable detail and its significance emphasized, as has also that at the base of the Pliocene in the vicinity of Alcalde Canyon.

[1] C. Wagner and K. Schilling, "The San Lorenzo Oligocene Series of the San Emigdeo Region," *Univ. Calif. Pub., Bull. Dept. Geol.*, Vol. 14 (1927), No. 6.

[2] G. Henny, "Some Notes on the Geology of the South San Joaquin Valley,' *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 11 (1927), p. 611.

[3] G. Henny, *op. cit.*, p. 615.

In the area just north of the Alcalde fault is still another overlap at the base of the Jacalitos (lower Pliocene) deposits. North of Coalinga and exposed in the nose of the Coalinga anticline are several thousand feet of Upper Cretaceous, Eocene, and Oligocene beds, all of which are absent in the section immediately west of the town of Coalinga. This great series of older Tertiary and Cretaceous deposits disappears within a distance of less than 10 miles along the strike. This overlap is undoubtedly closely associated with the block uplift on the Alcalde fault and the folding on the Coalinga anticline, to which reference has already been made.

North of the Coalinga anticline in the vicinity of Panoche valley is a very striking overlap; the Tulare deposits (equivalent in part to the "Paso Robles" of the U. S. Geological Survey in the southern part of the valley) are found lying on all the older formations, including the Cretaceous. This overlap is best developed on the top of the Ciervo anticline.

It is a significant fact that all the major overlaps and structural unconformities occur either close to the major lines of folding or in the vicinity of faulting, showing conclusively that the folding and faulting had a very early origin. As already stated, the writer believes there is good evidence that the folds were the result of compression along the faults; if this is so, the faults are older than the folds. Structural unconformities have been reported in several localities along the border. They do not, however, have any great lateral extent and almost invariably they are best developed on the top of a major anticline, whereas in the syncline and in the areas between, where no marked folding has taken place, it is ordinarily difficult to find these same contacts.

DELTA DEPOSITS ALONG THE WESTERN BORDER AREA OF THE VALLE GRANDE

All the evidence at hand seems to show that it was only during the Miocene that any large part of the Coast Ranges west of the Valle Grande was inundated; even then only a few of the positive blocks were covered until upper Miocene time, and these only in the area south of San Francisco Bay. Throughout Cretaceous and Tertiary times land masses separated the Valle Grande from the Pacific Ocean, and the sediments found in the western border area were derived from these western land areas.

Reference has been made, in the discussion of the border area of the Mount Hamilton block, to the great thickness of conglomerates

in the lower Panoche formation (Cretaceous) and to the evident derivation of the boulders in these conglomerates from the granites of the Gabilan area and from the members of the Franciscan series (pp. 226-27). The granitic boulders must have been carried across a land mass formed of the Mount Hamilton block. The best exposure of these conglomerates is found on Quinto Creek. Here at the base of the Cretaceous is a series of conglomerates, almost 5,000 feet thick, containing lenses of sandstones and shales. These conglomerates thin out within short distances toward the north and south. There can be little doubt that this is a cross section of an old delta, the deposits of which came from the west, the great thickness being due to the fact that the sediments were accumulating in the basin, which at the same time was being depressed along the western zone of faulting.

Probably when the Cretaceous and Tertiary deposits of the western border area of the Valle Grande have been mapped and studied more in detail, it will be found that there is evidence of a number of old deltas, which were the result of rivers dumping their load into this basin. The several thousand feet of arkosic Eocene deposits near Devil's Den, and their rapid thinning out toward the north, point to a possible old delta in that region. The Cantua sandstone in the Eocene section on the north flank of the Coalinga anticline, which member was mapped by Anderson and Pack,[1] also suggests an old delta; here are approximately 2,000 feet of coarse, cross-bedded, arkosic sandstones coming in within a very short distance. The arkosic sandstones of the Markley formation,[2] found in the Oligocene section on the north side of Mount Diablo, may be explained in the same way. Still other examples could be given. None of these old possible deltas can be described in detail, because sufficient field work has not been done in those areas. The western border area offers, from this point of view, some interesting problems in sedimentation. Very little of this type of work has been done in California.

SUMMARY OF CONCLUSIONS

1. The Valle Grande, the modern representative of which is the Great Valley of California, originated as a complex fault trough.

2. It has existed as a negative area since early Mesozoic time.

[1]Robert Anderson and Robert Pack, "Geology and Oil Resources of the San Joaquin Valley North of Coalinga, California," *U. S. Geol. Survey Bull. 603* (1915), p. 59, pl. 1.

[2]B. L. Clark, "The San Lorenzo Series of Middle California," *Univ. Calif. Pub., Bull. Dept. Geol.*, Vol. 11, No. 2 (1918), pp. 84-85.

3. The Coast Ranges west and south of the Valle Grande have, in large part, been positive during the time that it was negative; while the one was rising, the other was sinking, and the sediments in the latter were being derived in part from the former.

4. The west and south sides of the Valle Grande were formed by faulting. Faults are also found on the east side of the south part of the basin, but the greatest depression has been on the west and south sides.

5. The faults on the west side of the Valle Grande have, in general, a common trend a little west of north and are almost parallel; each forms a part of the border, and finally most of them disappear at the southeast in the folded sediments of the basin.

6. Besides the faults which formed the west side of the Valle Grande there are others that branch out from the west zone of faulting and either disappear in the folded sediments or are covered by the alluvium of the valley. Some of these are primary and may correspond with faults found in the mountains on the southeast.

REVIEWS AND NEW PUBLICATIONS

"*Foraminifera*: Their Classification and Economic Use." By JOSEPH A. CUSHMAN. *Cushman Laboratory for Foraminiferal Research* (Sharon, Massachusetts), *Spec. Pub. No. 1* (April, 1928). 401 pp. Price, $5.00.

This admirable work, now well known to micropaleontologists, deserves wide notice and should be called to the attention of all who are interested in the subject of fossil or recent *Foraminifera*. It is a comprehensive, readable, and very well-illustrated text that furnishes the best existing introduction to a broad and somewhat difficult field that is rapidly increasing in importance as applied to oil-field stratigraphic problems.

Concise discussions of morphology, habits, geologic and geographic distribution, and very useful suggestions on laboratory technique make up the introductory chapters. The main body of the work is devoted to a description of 412 genera, each illustrated by figures most of which represent the genotypes. Extensive and important changes in nomenclature are introduced to accord with zoölogical rules. The substantiation of many of these changes and the correction of synonymy required of the author considerable study of type material in European museums. The described genera are grouped in 45 families, and an attempt is made to arrange these in a natural or phylogenetic classification. Artificial keys for identification of families and of many genera are a very great aid to the student. Consideration of the interesting subject of trimorphism and a well-selected, rather extensive bibliography complete the book. The volume has a pleasing appearance and contains a minimum of typographical errors. It is indispensable to the library of the paleontologist, and should be in the hands of all interested geologists.

RAYMOND C. MOORE

LAWRENCE, KANSAS
January, 1929

"Quantitative *vs.* Qualitative Studies in Geology." By GEORGE D. HUBBARD. *Science*, n. s. Vol. 68, No. 1756 (August 24, 1928), pp. 171-74.

Geologists, in general, have failed to keep pace with physicists and chemists in determining and recording the quantitative data of their science. True, a start has been made toward exactness by the petrographers and petrologists in their measurement of crystals and analyses of minerals and rocks. A few studies of the rate of erosion have been made. Vulcanologists are beginning to accumulate data through the work at Kilauea. However, on the whole, little effort has been made to secure exact measurement of geologic processes.

Among the determinations that might be begun are the rate of recession of falls and the rate of the cutting of valleys. Measurements made and recorded

now could be repeated many years hence and a true idea of the rapidity of erosion under a variety of conditions could thus be secured. The changes in meandering streams, the rates at which they cut their banks on the one hand and build up their flood plains on the other are equally determinable. The rate, direction, frequency, and continuity of movement along active faults need not be guessed at. The rate of weathering of different rocks and minerals under diverse climatic conditions should be measured, not estimated. Shore lines can be surveyed to determine both how fast the sea cliffs recede and how fast the beaches and deltas are built. The rate of deposition of sand, clay, and calcium carbonate can be established by a series of measurements taken through a period of years.

Of course many of these measurements could not be completed in one man's lifetime, but if they are initiated by individuals or institutions, others can carry them forward.

The reviewer recalls a law suit, the cause of which was the subsidence of the surface of an oil field, this sinking amounting to about 3¼ feet in 7 years. The fact that the subsidence was, correctly or incorrectly, ascribed to the withdrawal of oil, gas, and sand from the field takes nothing from the interest and importance of the problem. In fact, the uncertainty about the cause of the subsidence adds to the importance of determining whether similar subsidences are in progress at other oil fields. This should be determinable and is a problem that is surely of interest to oil geologists. An analogous problem is the subsidence, if such subsidence occurs, in districts where much water has been taken from the ground for irrigating purposes. Again, it is not uncommon for a farmer to report that he selected the site for his house because at the time it was built he could see all parts of his farm from it, and that now there is some part of the farm that is not visible. This report crops up so often that there is reason to believe local uplifts and subsidences do take place and that, through a period of 20 or 30 years, they are extensive enough to be detectable without very precise measurements. All this argues for extensive levelling work, and even more does it argue for the preservation of records of such levelling at some institution where those records will be available for consultation.

Observations that can be made by the individual field geologist include such records as the rate of erosion of gulleys and ravines, and the rate of sedimentation or deflation. Where such processes are active, observations can be made with sufficient accuracy to permit the same geologist or another who visits the site at a later time to determine just what has taken place in the interval between observations. For some purposes photographs should prove excellent records provided enough care is used in describing the exact position and orientation of the camera, and in selecting a spot for setting up the camera that can be easily found and reoccupied by a subsequent observer. Here again it is vital that there be a record bureau where such observations may be preserved, tabulated, and studied.

The reviewer would suggest that state universities, strongly endowed private universities, state geological surveys, and the United States Geological Survey are logical depositories, but, of course, only those should be selected that are willing to make definite provision for preserving these records. Such

depositories are needed to-day, if only to accumulate and study the data that can be secured without the initiation of new studies.

K. C. HEALD

PITTSBURGH, PENNSYLVANIA
January 25, 1929

RECENT PUBLICATIONS

GENERAL

"The Seismograph in the Gulf Coast," by Mark C. Malamphy. *Oil Weekly* (Jan. 18, 1929), pp. 31-34; 3 figs.

"Modern Methods for Measuring the Intensity of Gravity." *U. S. Coast and Geod. Survey Spec. Pub. 69.* Superintendent of Documents, Washington, D. C. Price, $0.15.

"Earthquake History of the United States Exclusive of the Pacific Coast." *U. S. Coast and Geod. Survey Spec. Pub. 149.* Superintendent of Documents, Washington, D. C. Price, $0.15.

"Topographic Manual," *U. S. Coast and Geod. Survey Spec. Pub. 144.* Superintendent of Documents, Washington, D. C. Price, $0.30.

"Review of the Late Paleozoic Formations and Faunas with Special Reference to the Ice-Age of Middle Permian Time," by Charles Schuchert. *Bull. Geol. Soc. Amer.*, Vol. 39, No. 3 (Sept., 1928), pp. 769-886.

"Geophysical Prospecting: Some Electrical Methods," by A. S. Eve and D. A. Keys. *U. S. Bur. Mines Tech. Paper 434* (Washington, D. C.). 41 pp., 33 figs. Price, $0.10.

MEXICO

"Geology of Southern Oaxaco, Mexico," by R. H. Palmer. *Jour. Geol.*, Vol. 36, No. 8 (Nov.-Dec., 1928), pp. 718-34.

NEW MEXICO

"Geologic Map of New Mexico," prepared by N. H. Darton. *U. S. Geol. Survey* (Washington, D. C.). The first large colored geologic map of the entire state. In two sheets flat or folded and inserted in a cover 19 × 26 inches. Price, $1.50.

OKLAHOMA

"Oil and Gas Geology of Oklahoma County," by C. L. Cooper. *Oklahoma Geol. Survey Prelim. Rept.* (Norman, Feb., 1929). 25 pp. (mimeographed), 3 pls., 3 figs. Price, $0.26.

"Faunal Chart of Mississippian and Morrow Formations of Oklahoma and Arkansas," by Robert Roth. *Oklahoma Geol. Survey Circular 18* (Feb., 1929). Price, $0.30.

TEXAS

"Handbook of Texas Cretaceous Fossils," by W. S. Adkins. *Bur. of Econ. Geol. Bull. 2838* (Austin, 1928). 385 pp., 37 plates. Price, paper, $2.25; cloth, $3.00.

THE ASSOCIATION LIBRARY

Headquarters acknowledges library accessions:

ALSACE

From Jean Jung:

"Les Recherches Récentes de Pétrole en Alsace"

GEOPHYSICS

From C. A. Heiland:

American Geophysical Union "Symposium and Discussion on Geophysical Methods as Applied in the Study of Geological Structure"

"Magnetoretric Investigations of Gold Placer Deposits near Golden, Colorado"

"Modern Instruments and Methods of Seismic Prospecting"

"Theory of Adolf Schmidt's Horizontal Field Balance"

From the National Research Council:

"Report of the Committee on Sedimentation, 1927-1928, W. H. Twenhofel, Chairman"

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following applicants for membership in the Association. This does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these applicants, please send it promptly to J. P. D. Hull, Business Manager, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each applicant.)

FOR ACTIVE MEMBERSHIP

John L. Church, Los Angeles, Calif.
Roderick Burnham, Earl B. Noble, C. R. McCollom
Carey G. Croneis, Chicago, Ill.
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Wienand K. Esgen, Cisco, Tex.
M. G. Cheney, W. L. Goldston, Jr., Wallace E. Pratt
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David M. Delo, Midland, Tex.
F. B. Plummer, E. H. Sellards, Raymond C. Moore
Burnell L. Graham, Bartlesville, Okla.
William F. Absher, A. F. Morris, J. M. Nisbet
Frank Herring, Breckenridge, Tex.
D. E. Lounsbery, H. P. Bybee, E. R. Elledge

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E. B. Branson, W. A. Tarr, Anthony Folger
Oleta May Richey, San Angelo, Tex.
D. E. Lounsbery, H. P. Bybee, E. H. Sellards
Fred Alton Schell, Jr., Tulsa, Okla.
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Jerry E. Upp, Lincoln, Neb.
E. F. Schramm, Wilson B. Emery, Charles T. Lupton
Girard Wheeler, Bartlesville, Okla.
William F. Absher, A. F. Morris, J. M. Nisbet

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G. C. Potter, T. E. Weirich, E. W. McCrary
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Dollie Radler, Sidney Powers, A. R. Denison

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J. Whitney Lewis, Burton Hartley, W. L. Goldston, Jr.
Robert L. McLaren, Eastland, Tex.
E. W. Owen, H. B. Fuqua, B. E. Thompson
Raymond F. McMillen, Tulsa, Okla.
Thomas W. Leach, Frank C. Greene, T. E. Weirich
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R. M. Gawthrop, Luther H. White, H. W. Peabody
Thomas F. Newman, Abilene, Tex.
R. Clare Coffin, Harold T. Morley, C. Max Bauer
Herman J. Owen, Owensboro, Ky.
E. R. Brockway, Charles E. Decker, William F. Absher
Ernest K. Parks, San Francisco, Calif.
Austin Cadle, Earl W. Wagy, S. H. Gester
Roy C. Quiett, Seminole, Okla.
R. J. Riggs, C. W. Roop, W. L. Day
Richard C. Reese, Los Angeles, Calif.
Joseph Jensen, Glenn D. Robertson, H. J. Steiny
George J. Smith, Los Angeles, Calif.
Roy R. Morse, E. F. Davis, M. G. Edwards
Thomas G. Taylor, Muskogee, Okla.
Colin C. Rae, W. T. Thom, Jr., Hale B. Soyster
Joseph Harold Turner, Abilene, Tex.
Paul B. Hunter, M. G. Cheney, A. I. Levorsen

A NEW GRAPHICAL METHOD FOR TORSION BALANCE-TOPOGRAPHIC CORRECTIONS AND INTERPRETATIONS

A CORRECTION

Word has been received from D. C. Barton that the diagram illustrated in Figure 1 of the article written by C. A. Heiland on "A New Graphical Method for Torsion Balance-Topographic Corrections and Interpretations" does not hold for infinite or 2-dimensional, but for 3-dimensional structures. Inasmuch as the article of D. C. Barton from which this illustration was taken did not contain a statement to that effect, the author mistook this diagram for a vertical graticule for 2-dimensional effects, as the latter have very much the same appearance as the former. Vertical diagrams for 2-dimensional structures may be found in a more recent article by D. C. Barton just published ("Calculations in the Interpretation of Observations with the Eötvös Torsion Balance," Geophysical Volume, *Trans. Amer. Inst. Min. Met. Eng.*, January, 1929).

C. A. H.

GEOLOGISTS AND LANDOWNERS

The Committee on Criminal Jurisprudence of the Texas Senate has had under consideration Senate Bill No. 438, requiring a permit in writing to be obtained from landowners where a person might desire to make examinations "to ascertain the presence of oil, gas or other minerals," and providing a fine of $1,000 and 60 days in jail for violations. An amendment provides exemption to Federal and State surveys and to students.

Numerous objections can be advanced against this bill, the principal one being that it makes a geologist a special kind of trespasser. The matter of illegal entry or trespass is well covered by law. The bill is based on the mistaken idea that by examining a particular tract of land the presence of oil can be determined thereon.

The operation of geophysical instruments may have caused the situation. The companies operating torsion balances and seismographs in Texas have always obtained and paid for permits. A few geophysical crews, through error or otherwise, have trespassed, resulting in actions for real or imaginary damages.

There is no way of telling what might be done with this bill. It is sufficient to say that something new to legislate against has been found, and it is possible that more bills of this type may be introduced in Texas and other states.

Resolutions by geological societies, solemnly passed and widely distributed, will do very little good at present. There are men who watch legislation and know the ways of the legislative bodies, who can give proper advice, and to these geologists should turn before stirring up sentiment. Publicity may do as much harm as good, as some legislative acts are pushed much more vigorously when opposition develops than they would have been if the matter had been quietly pursued.

Geologists should realize that their activities are becoming more and more a matter of public and political concern, and although they are usually welcome visitors in any district, they should be extremely careful in their field work to respect the rights of landowners.

FINANCIAL STATEMENT, 1928

The 1928 audit of the Association shown herewith is much more complete and comprehensive than has ever before been made. Heretofore the audit has consisted of a verification of the cash receipts and disbursements only, but in the statements published herewith—a balance sheet and a profit and loss account—there are listed the actual assets and liabilities of the Association, including an inventory of printed matter on hand, as well as the income and expenses properly applicable to the year 1928. Our books of account have been arranged to reflect this condition in the future. The executive committee is anxious that this system of auditing which has been established shall be continued from year to year.

WILLSON & GARNETT, CERTIFIED PUBLIC ACCOUNTANTS,
Kennedy Building, Tulsa, Oklahoma, February 15, 1929.

MR. R. S. MCFARLAND, President,
American Association of Petroleum Geologists, Tulsa, Oklahoma.

DEAR SIR:

At your request we have made an examination of the books and records of the American Association of Petroleum Geologists, Tulsa, Oklahoma, for the purpose of redetermining the financial condition of the Association at December 31, 1928, and the result of its operations for the year then ended.

After adjusting the accounts so as to show the income and expenses applicable to the year under review, we have prepared, and submit herewith, the following exhibits and schedules.

Exhibit A—Balance Sheet as at December 31, 1928
  Schedule A-1—Inventory of Printed Matter on hand at December 31, 1928
  Schedule A-2—Investments at December 31, 1928
Exhibit B—Statement of Income and Expenses for the year 1928
  Schedule B-1—Cost of Printed Matter sold (General Fund)

With respect to the statements submitted, we offer the following comments.

Cash in banks was verified by means of statements furnished by the depositories.

We made an actual count of the printed matter on hand and at the printers as set forth in Schedule A-1. This inventory is priced at cost.

A list of the investments of the Association is given in Schedule A-2, the values being stated at cost. We have not attempted to determine the market value of these securities.

Furniture and Equipment were subjected to depreciation at the rate of 10 per cent per annum, which we consider sufficient.

Deferred Income consists of subscriptions, dues, and advertising charges collected in 1928 but applicable to the year 1929.

We adjusted the surplus shown by the books at December 31, 1928, to show as follows.

	General Fund	*Publication Fund*	*Total*
At December 31, 1927	$29,411.61	$4,124.72	$33,536.33
Add:			
Net Profit or Loss, Year 1928	10,157.50	−884.04	9,273.46
Total	$39,569.11	$3,240.68	$42,809.79

The statement of Income and Expenses for the year 1928 (Exhibit B), is given in considerable detail and supported by Schedule B-1, representing the cost of printed matter sold. We have included in this statement only income and expenses properly applicable to the year 1928.

We have verified sufficient of the detail of the records to be convinced of their clerical accuracy.

Should you desire any further information with respect to the work performed, or the statements submitted, we shall be pleased to furnish it upon request.

Respectfully submitted,

(*Signed*) WILLSON & GARNETT

Certified Public Accountants

EXHIBIT A

BALANCE SHEET—DECEMBER 31, 1928

ASSETS

	General Fund	Publication Fund	Total
CURRENT ASSETS			
Cash in Banks	$ 3,671.59	$ 995.53	$ 4,667.12
Accounts Receivable	996.95	12.95	1,009.90
Inventory of Printed Matter on Hand (Schedule A-1)	11,601.35	504.32	12,105.67
Total Current Assets	$16,269.89	$1,512.80	$17,782.69
INVESTMENTS			
Bonds and Savings Certificates (Schedule A-2)	25,633.75	1,937.39	27,571.14
FIXED ASSETS			
Office Furniture and Equipment, at depreciated value	1,881.07		1,881.07
DEFERRED ITEMS			
Insurance Premiums paid in advance	106.83		106.83
Total Assets	$43,891.54	$3,450.19	$47,341.73

LIABILITIES

	General Fund	Publication Fund	Total
CURRENT LIABILITIES			
Salary and Sundry Accounts Payable	$236.86	$209.51	$446.37
DEFERRED INCOME			
Subscriptions, Dues and Advertising paid in Advance	4,085.57		4,085.57
SURPLUS			
At December 31, 1928	39,569.11	3,240.68	42,809.79
Total Liabilities and Surplus	$43,891.54	$3,450.19	$47,341.73

SCHEDULE A-1

INVENTORY OF PRINTED MATTER ON HAND DECEMBER 31, 1928

GENERAL FUND

BULLETINS (UNBOUND)			Stock	*Printing Cost—Item*	Cost
Vol. 2		1918	181	$1.15	$208.15
Vol. 3		1919	107	1.80	192.60
Vol. 4	No. 2	1920	49	1.13	55.37
Vol. 4	No. 3	1920	59	1.13	66.67
Vol. 5	No. 2	1921	119	.90	107.10
Vol. 5	No. 3	1921	193	.37	71.41
Vol. 5	No. 4	1921	205	.30	61.50
Vol. 5	No. 5	1921	167	.40	66.80
Vol. 5	No. 6	1921	56	.32	17.92
Vol. 6	No. 1	1922	7	.29	2.03
Vol. 6	No. 2	1922	92	.39	35.88
Vol. 6	No. 3	1922	192	.40	76.80
Vol. 6	No. 4	1922	181	.37	66.97
Vol. 6	No. 5	1922	233	.35	81.55
Vol. 6	No. 6	1922	221	.29	64.09
Vol. 7	No. 1	1923	186	.61	113.46
Vol. 7	No. 2	1923	76	.60	45.60
Vol. 7	No. 3	1923	41	.55	22.55
Vol. 7	No. 4	1923	115	.66	75.90
Vol. 7	No. 5	1923	110	.63	69.30
Vol. 7	No. 6	1923	62	.64	39.68
Vol. 8	No. 1	1924	241	.68	163.88
Vol. 8	No. 2	1924	1	.62	.62
Vol. 8	No. 3	1924	145	.79	114.55
Vol. 8	No. 4	1924	182	.65	118.30
Vol. 8	No. 5	1924	292	.69	201.48
Vol. 8	No. 6	1924	229	.89	203.81
Vol. 9	No. 1	1925	72	.82	59.04
Vol. 9	No. 2	1925	68	1.38	93.84
Vol. 9	No. 3	1925	75	1.27	95.25
Vol. 9	No. 4	1925	123	.49	60.27
Vol. 9	No. 5	1925	80	.39	31.20
Vol. 9	No. 6	1925	93	.49	45.57
Vol. 9	No. 7	1925	129	.42	54.18
Vol. 9	No. 8	1925	97	.56	54.32
Vol. 9	No. 9	1925	150	.44	66.00
Vol. 10	No. 1	1926	112	.39	43.68
Vol. 10	No. 2	1926	26	.49	12.74
Vol. 10	No. 3	1926	113	.64	72.32
Vol. 10	No. 4	1926	159	.38	60.42
Vol. 10	No. 5	1926	158	.34	53.72
Vol. 10	No. 6	1926	186	.39	72.54
Vol. 10	No. 7	1926	207	.35	72.45
Vol. 10	No. 8	1926	160	.28	44.80
Vol. 10	No. 9	1926	230	.35	80.50
Vol. 10	No. 10	1926	172	.38	65.36
Vol. 10	No. 11	1926	112	.54	60.48
Vol. 10	No. 12	1926	141	.58	81.78
Vol. 11	No. 1	1927	1	.38	.38
Vol. 11	No. 2	1927	5	.44	2.20

GENERAL FUND—*Continued*

			Stock	Printing Cost—Item	Cost	
BULLETINS (UNBOUND)						
Vol. 11	No. 3	1927	3	.47	1.41	
Vol. 11	No. 4	1927	18	.32	5.76	
Vol. 11	No. 5	1927	30	.39	11.70	
Vol. 11	No. 6	1927	95	.37	35.15	
Vol. 11	No. 7	1927	7	.44	3.08	
Vol. 11	No. 8	1927	52	.44	22.88	
Vol. 11	No. 9	1927	34	.45	15.30	
Vol. 11	No. 10	1927	54	.34	18.36	
Vol. 11	No. 11	1927	76	.39	29.64	
Vol. 11	No. 12	1927	31	.50	15.50	
Vol. 12	No. 1	1928	26	.42	10.92	
Vol. 12	No. 2	1928	23	.43	9.89	
Vol. 12	No. 3	1928	36	.43	15.48	
Vol. 12	No. 4	1928	45	.41	18.45	
Vol. 12	No. 5	1928	47	.48	22.56	
Vol. 12	No. 6	1928	49	.36	17.64	
Vol. 12	No. 7	1928	134	.39	52.26	
Vol. 12	No. 8	1928	60	.36	21.60	
Vol. 12	No. 9	1928	105	.35	36.75	
Vol. 12	No. 10	1928	86	.35	30.10	
Vol. 12	No. 11	1928	81	.35	28.35	
Vol. 12	No. 12	1928	63	.35	22.05	
BULLETINS (BOUND)						
		1921	91	4.02	365.82	
		1922	31	3.41	105.71	
		1923	34	4.38	148.92	
		1924	36	5.35	192.60	
		1925	92	3.99	367.08	
		1926	88	3.59	315.04	
		1927	410	3.36	1,377.60	
INDEX			1,687	.50	843.50	
SALT DOME VOLUME			96	1.94	186.24	$7,974.35
BULLETINS (UNBOUND AT PRINTERS)						
Vol. 12	No. 1	1928	775	$ .42	$325.50	
Vol. 12	No. 2	1928	775	.43	333.25	
Vol. 12	No. 3	1928	775	.43	333.25	
Vol. 12	No. 4	1928	775	.41	317.75	
Vol. 12	No. 5	1928	775	.48	372.00	
Vol. 12	No. 6	1928	775	.36	279.00	
Vol. 12	No. 7	1928	775	.39	302.25	
Vol. 12	No. 8	1928	775	.36	279.00	
Vol. 12	No. 9	1928	775	.35	271.25	
Vol. 12	No. 10	1928	775	.35	271.25	
Vol. 12	No. 11	1928	775	.35	271.25	
Vol. 12	No. 12	1928	775	.35	271.25	3,627.00
TOTAL INVENTORY, GENERAL FUND						$11,601.35

PUBLICATION FUND

	Stock	Printing Cost—Item	
CONTINENTAL DRIFT	256	$1.97	504.32
TOTAL INVENTORY			$12,105.67

SCHEDULE A-2

INVESTMENTS—DECEMBER 31, 1928

BONDS (GENERAL FUND)	*Interest Rate Per Cent*	*Par Value*	*Cost*
Allied Owners Corporation	6	$1,000.00	$ 990.00
Allied Owners Corporation	6	1,000.00	990.00
Argentine Government External Loan	6	1,000.00	997.50
Exchange National Company	5½	500.00	500.00
Exchange National Savings Bond	5½	1,100.00	1,100.00
Hardin County, Texas, Road Bond	5	1,000.00	984.20
Imperial Japanese Government	6½	500.00	462.50
Indiana Hydro-Electric Corporation	5	3,000.00	2.910.00
Middle West Utilities	5½	1,000.00	993.00
Middle West Utilities	5½	1,000.00	998.80
Nevada-California Electric Corporation	5	3,000.00	2.865.00
Northern State Power Company	6	1,500.00	1,493.25
Pondera County, Montana, Refunding	5½	1,000.00	1,000.00
Pure Oil Company	5½	1,000.00	990.00
United States Rubber Company	5	1,000.00	859.50
TOTAL BONDS			$18,133.75
CERTIFICATES (GENERAL FUND)			
Morris Plan Company		$7,500.00	$ 7,500.00
TOTAL (GENERAL FUND)			$25,633.75
CERTIFICATES (PUBLICATION FUND)			
Morris Plan Company		$1,937.39	$ 1,937.39
TOTAL INVESTMENTS			$27,571.14

EXHIBIT B

STATEMENT OF INCOME AND EXPENSES

YEAR 1928

INCOME		General Fund	Publication Fund	Total
Membership Dues—				
Associate	$ 7,044.00			
Active	20,171.10	$27,215.10		
Bulletins—				
Subscriptions	$ 4,130.04			
Sale of Bound Copies	3,916.58			
Sale of Indices	236.90			
Sale of Back Numbers	1,379.87			
Advertising	3,994.74	13,658.13		
Sale of Salt Dome Volume		791.46		
Sale of Continental Drift			$2,192.79	
TOTAL INCOME FROM OPERATIONS		$41,664.69	$2,192.79	$43,857.48
EXPENSES				
Cost of Printed Matter Sold (Schedule B-1)	$13,587.30			
Printing Separates	482.65			
Stencil Corrections and Mailing	635.70			
Freight, Express and Sundry	386.68			
Salary Editorial Secretary	2,896.15	17,988.48		
Expense Continental Drift			2,241.23	20,229.71
GROSS PROFIT OR LOSS		$23,676.21	$ −48.44	$23,627.77
GENERAL OFFICE EXPENSE				
Salary Business Manager	$ 7,500.00			
Salaries, Clerical	3,417.50			
Telephone, Telegraph, Postage	1,440.44			
Printing, Stationery, and Supplies	1,282.98			
Traveling and Convention Expense	615.86			
Insurance	122.03			
Depreciation	169.83			
Donations	1,050.00			
Freight and Sundry	414.54	16,013.18		
Symposium			939.63	16,952.81
PROFIT OR LOSS FROM OPERATION		$ 7,663.03	$−988.07	$ 6,674.96
OTHER INCOME				
Interest on Investments	$ 2,355.13		$ 104.03	
Sundry	139.34	2,494.47		2,598.50
NET PROFIT OR LOSS FOR YEAR 1928		$10,157.50	$−884.04	$ 9,273.46

SCHEDULE B-1

COST OF PRINTED MATTER SOLD

GENERAL FUND

INVENTORY OF PRINTED MATTER ON HAND JANUARY 1, 1928		$ 7,688.30
COST OF PRINTING, 1928		
Volume 12, No. 1	$1,386.25	
Volume 12, No. 2	1,429.50	
Volume 12, No. 3	1,405.85	
Volume 12, No. 4	1,334.90	
Volume 12, No. 5	1,582.08	
Volume 12, No. 6	1,191.77	
Volume 12, No. 7	1,300.12	
Volume 12, No. 8	1,191.77	
Volume 12, No. 9	1,129.13	
Volume 12, No. 10	1,153.88	
Volume 12, No. 11	1,150.50	
Volume 12, No. 12	1,126.65	
CLOTH BINDING	1,115.25	
ENGRAVING	1,002.70	17,500.35
		$25,188.65
Less: Inventory December 31, 1928		11,601.35
COST OF PRINTED MATTER SOLD (GENERAL FUND)		$13,587.30

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
MEMBERSHIP LIST

March 1, 1929

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The executive committee may from time to time elect as honorary members persons who have contributed distinguished service to the cause of petroleum geology. Honorary members shall not be required to pay dues, nor shall they be allowed to vote.—*Sec. 7, Article III, of the Constitution.*

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Any person actively engaged in the work of petroleum geology or in research pertaining to petroleum geology or technology is eligible to active membership in the American Association of Petroleum Geologists, provided he is a graduate of an institution of collegiate standing, in which institution he has done his major work in geology, and in addition has had the equivalent of three years' field experience in petroleum geology; and provided further that in case of an applicant for membership who has not had the required collegiate or university training, but whose standing in the profession is well recognized, he shall be admitted to membership when his application shall have been favorably and unanimously acted upon by the executive committee; and provided further that these requirements shall not be construed to exclude instructors and professors in recognized institutions of learning whose work is of such a character as in the opinion of the executive committee shall qualify them for membership.—*Sec. I, Article III, of the Constitution.*

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Any person having completed as much as thirty hours of geology (an hour shall here by interpreted as meaning as much as sixteen recitation or lecture periods of one hour each, or the equivalent in laboratory) in a reputable institution of collegiate or university standing, or who has done field work equivalent to this, shall be eligible to associate membership in the American Association of Petroleum Geologists, provided that at the time of his application for membership he shall be engaged in geological studies in an institution of collegiate or university standing, or shall be engaged in geological work. *Sec. 2.*

Associate members shall enjoy all privileges of membership in the Association, save that they shall not hold office, sign applications for membership, or vote in business meetings; neither shall they have the privilege of advertising their associate membership in the Association in professional cards, nor shall they have the privilege of signing professional reports as associate members of the Association.—*Sec. 4, Article III, of the Constitution.*

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Memorial

JULIUS SEGALL

Julius Segall died suddenly at Los Angeles on November 27, 1928. Mr. Segall was born in New York in 1884. He was unmarried. He received the Bachelor of Science degree from the University of Wisconsin in 1914 and a Master's degree from the University of Minnesota in 1915.

Mr. Segall did engineering work on the Mesabi Range before entering college, and considerable geological work in the Lake Superior region during vacations. He was with the E. J. Longyear Company in Arkansas on extensive bauxite explorations for the Aluminum Company of America. Then followed several years, mainly in Oklahoma, in oil work, and later with the Greenwood Oil Company which took him to Texas and Louisiana. He served during the World War, doing photographic work in the Air Service. Soon after the war he went to Mexico City to look after oil concessions of the El Oro Company and remained there until 1922. Since 1923, Mr. Segall made his headquarters at Los Angeles and became well acquainted with the oil fields of that vicinity. An engagement in New Mexico early in 1927 for George F. Getty resulted in that concern entering the southeastern New Mexico area. He maintained an office in the Rowan Building with R. M. Hunt.

Mr. Segall was a member of Sigma Xi, honorary scientific society, A. I. M. & M. E., a member of the executive committee of Southern California Section, A. I. M. & M. E., Society of Economic Geologists, American Association of Petroleum Geologists, Engineers Club, and the American Legion. He was also a member of the Sea Breeze Beach Club.

Mr. Segall's professional work was careful and painstaking and his standing among geologists was very high. Many beautiful plates in United States Geological Survey Monograph 52, on the Lake Superior region, are the product of his skill in drawing. The unfolding of his character and personality in the twenty years the writer knew him revealed him to be a gentleman of rare accomplishments. Flashes of recollection—a colored photograph of Zumate—a snow-laden camp in the Wisconsin woods—a famous old violin played by an artist—an excellent appreciation of music and opera—a romp with some of the many children who adored him—a meal or a loan to a stranded ex-service man in Mexico City—a host of devoted friends in every walk of life—these and other significant impressions of his personality will keep his memory with us as long as we live. Good, brave, true Julius.

ORRIN F. PETERSON

EDWIN BINNEY, JR.

Edwin Binney, Jr., died in Pasadena, California, December 29, 1928, of paralysis with complications, probably induced by sleeping sickness con-

tracted years ago in the Monroe district of Louisiana while working for the Columbian Carbon Company.

Edwin Binney was born in Sound Beach, Connecticut, March 20, 1899. He took his Bachelor's degree from Yale in 1921 and his Ph. D. in 1925. He served as an instructor in Yale in 1926-27 and thereafter held the rank of research assistant geologist, studying in particular the origin and geologic association of natural gas. Since 1923 he had been working under the auspices of the National Research Council on the occurrence and origin of natural gas, seeking the explanation for the many puzzling relationships between natural gas and petroleum and between natural gas and the rocks in which it is found and with which it is associated. In the course of this study he visited most of the natural gas fields in the United States and made a number of important contributions to our knowledge of the geology and occurrence of gas in those fields.

Dr. Binney possessed a remarkable combination of enthusiasm and keen interest in the study of geology which, but for his untimely death, would have made him an outstanding figure in his chosen field. The Association and the science of geology have suffered deeply by this loss.

K. C. Heald

Pittsburgh, Pennsylvania
January, 1929

JEAN CLEVELAND THOMPSON

Jean Cleveland Thompson died January 13, 1929, from a severe attack of influenza complicated by pneumonia and erysipelas, and was buried with military honors in Tulsa, January 15.

Thompson was born in Wheeler County, Texas, April 12, 1887. While Jean was still a boy, his father moved to Madill, Oklahoma, and a little later settled on a ranch near Sayre. It was here that Jean lived until he entered the preparatory department of the University of Oklahoma in the fall of 1905. "Tommy," as he came to be affectionately called by his many friends, was one of the most popular men in school. He completed his university course and graduated in geology in 1912. He was captain of the football team in 1910, and was elected the first president of the Student Council, the student governing body of the university.

After graduation he was athletic director and football coach for Oklahoma City High School for three years.

His geological work was begun with the Oklahoma Geological Survey. Later he went with the United States Geological Survey, doing detailed mapping in northern Oklahoma and southern Kansas.

At the beginning of the trouble on the Mexican border, Tommy enlisted in the army. During this service he was commissioned a first lieutenant, and for some time was aide to General Roy Hoffman. He joined the army again when the United States entered the World War, and served overseas for nearly two years. He saw considerable active service, engaging in many of the most notable battles of the war, including Montidider Noyon, Champayne Marne,

Aisne Marne, and Meuse Argonne. He was once gassed and twice wounded in action. He rose to the rank of captain, and was in command of the Headquarters Company, 3rd Army Corps, A. E. F. He received his honorable discharge at Camp Pike, Arkansas, August 5, 1919, and later was given a commission as captain of infantry in the Officers Reserve Corps.

At the close of the war he attended Edinburg University, Scotland, for one year, taking special work in geology. After returning to this country he resumed his geological work, becoming associated with the Middle States Oil Company. Until 1922 he spent most of his time in Texas, becoming production superintendent for this company. He then came to Tulsa and entered the employ of the Meridian Petroleum Corporation.

In 1924 he accepted the position of deputy warden of the Oklahoma State Penitentiary, through the persuasion of Col. W. S. Key, an old wartime buddy of Tommy's, who was then warden, and remained in that position until January, 1927. He then returned to Tulsa and became associated with R. F. Garland.

On September 17, 1922, he was united in marriage to Miss Betty Donahoe of Oklahoma City, and to this happy union was born one daughter, Betty Jean, Both his wife and daughter were critically ill during his brief sickness, and at the time of his sudden death.

During Tommy's student days he was elected a charter member of the Sigma Nu fraternity. Later he became a member of the American Association of Petroleum Geologists, and the Tulsa Geological Society. He was a director of the Tulsa Athletic Club, a member of the American Legion, and a thirty-second-degree Mason.

Few men possess so wide a circle of close friends as did Tommy. His prominence in athletics during college days, his long and distinguished military service, and his widespread activities as a geologist and oil man gave him unequalled opportunities for acquiring friends, while his big-hearted, generous nature and cheerful disposition gave him a rare faculty for retaining them. He was a most conscientious and capable worker, a clean athlete, a loyal soldier, and a man absolutely consecrated to his family. He was big of heart as well as mind and body.

His sudden and untimely passing have been a profound shock and a severe loss to his family and host of friends.

ROBERT E. GARRETT

TULSA, OKLAHOMA
January 18, 1929

GENERAL BUSINESS COMMITTEE MEETING, FORT WORTH MARCH 20, 2 P. M.

The general business committee of the A. A. P. G. will meet at The Texas Hotel, at Fort Worth, Texas, at 2 P. M., March 20, 1929, the day before the fourteenth annual convention opens. Important business is to be transacted and it is expected that the committee meeting will be fully attended. President McFarland has appointed Max W. Ball to be chairman for this meeting, replacing C. R. McCollom who is unavoidably prevented from attending the convention.

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

George Otis Smith, director of the U. S. Geological Survey, is a member of the board of trustees of the University of Chicago.

The Kansas Geological Society announces that its third annual field conference will be held in the Black Hills of South Dakota early in September, 1929, under the direction of George F. Kay, state geologist of Iowa. For details address Anthony Folger, chairman of the committee, Box 1144, Wichita, Kansas.

Frederick G. Clapp has made recent trips to England and Switzerland and has returned to Paris, where his family is spending the winter.

George F. Barnwell, of the Standard Oil Company, returned to Java last January. His address is Med. Kol. Pet. Mij., Weltevreden, Java, D. E. I.

S. F. Shaw is visiting properties of the Standard Oil Company of New Jersey in Roumania, Poland, and Italy, to study possibilities of employing the gas lift and repressuring in those countries.

Edwin B. Hopkins, petroleum geologist, sailed on the S. S. Caracas for Venezuela last January.

J. B. Whisenant, geologist for The California Company, Dallas, has resigned to establish an office at Big Spring, Texas, as consulting geologist.

Harry L. Baldwin, formerly with the Marland Oil Company, is now with the Independent Oil and Gas Company. Mr. Baldwin's address is 600 West 20th Street, Oklahoma City, Oklahoma.

Robert McNeeley, formerly with the Marland Oil Company, is now with the Independent Oil and Gas Company. Mr. McNeeley is making Tulsa his headquarters.

The West Texas Geological Society, San Angelo, Texas, has elected the following officers for 1929: president, V. E. Cottingham; vice-president, A. L. Ackers; and secretary-treasurer, Stanley E. Jay, The Pure Oil Company, San Angelo.

Van H. Manning, director of research for the Petroleum Research Corporation of New York City, went to Havana, Cuba, in January, in connection with his duties as consulting petroleum engineer for the Republic of Cuba.

Eugene Holman, chief geologist of the Humble Oil and Refining Company at Houston, Texas, has been appointed assistant to E. J. Sadler, vice-president and director of the Standard Oil Company of New Jersey, in charge of foreign operations.

Lowell J. Ridings, geologist, is engaged in the work of examinations and appraisals in Mexico and South America. His address is Apartado 344, Tampico, Mexico.

The Geological Society of New Mexico has been organized with the following officers: president, Walter B. Lang, U. S. Geological Survey; vice-president, Frank Prout, Empire Oil and Gas Company; secretary, Burton Headley, Southern Petroleum Exploration, Inc., Box 781, Roswell; treasurer, Morgan J. Davis, Humble Oil and Refining Company.

Charles H. Pishney, formerly with the Marland Oil Company, is now on the engineering staff of the Amerada Petroleum Corporation, doing valuation work at Tulsa, Oklahoma.

Chester Naramore has resigned from the Sinclair Consolidated Corporation to become vice-president of Pettigrew and Meyer, Inc., in charge of field operations out of New York.

R. E. Collom is executive vice-president of the Marland Oil Company of California, in charge of California operations.

Paul P. Goudkoff, geologist, announces the removal of his offices to 1222-24 Subway Terminal Building, 417 South Hill Street, Los Angeles, California.

E. H. Sellards is chairman of the Division of Conservation and Development of Natural Resources of the University of Texas. This division includes the Bureau of Economic Geology, Bureau of Industrial Chemistry, and Bureau of Engineering Research.

W. B. Heroy, 45 Nassau Street, New York City, is a vice-president of the Venezuelan Petroleum Company.

David Donoghue, in charge of geological and lease-purchasing divisions of the Texas Pacific Coal and Oil Company at Fort Worth, Texas, is the author of "The Route of the Coronado Expedition in Texas," in the *Southwestern Historical Quarterly* for January, 1929.

J. C. Thompson, in charge of geological and production work for the Garland Oil Company at Tulsa, Oklahoma, died at Tulsa, January 13, 1929.

The Fifteenth International Geological Congress will be held under the auspices of the Geological Survey of South Africa at Pretoria, July 29 to August 7, 1929. Joseph T. Singewald, Jr., professor of economic geology at Johns Hopkins University, Baltimore, Maryland, who is one of the A. A. P. G. delegates, offers this information of interest to geologists who may have considered the expense and time required for this trip prohibitive to their attendance. "The American South Africa Line sails direct from New York to Capetown. The boats are small freighters with limited accommodations for passengers. The steamer Isleta sails from New York on June 1 and arrives at Capetown on July 1. She has four two-passenger staterooms. The fare is $325 one way and a discount of 10 per cent is allowed on round trip bookings, making the round trip only $585. Three persons who have made the trip on these boats tell me that the food is plain but good and clean, that the boats are clean, and that the officers are good company. If a group of geologists booked on this

boat they could have a very agreeable and congenial trip. The trip is made as rapidly as it can be done by the fastest trans-Atlantic steamers and the Royal Mail boats of the Union Castle Line and the round trip costs less than the one way fare by the latter route." The Congress membership fee is £1 sterling, payable in advance. Membership forms may be secured from the General Secretary, Box 391, Pretoria. A reduction of 20 per cent on the steamship rates has been granted to members of the Congress.

BASIL B. ZAVOICO, consulting geologist, has opened an office at 501 Philtower Building, Tulsa, Oklahoma.

R. A. BIRK, formerly with the Amerada Petroleum Corporation, is consulting geologist of the Bridwell Oil Company at Wichita Falls, Texas.

L. B. SNIDER has resigned from the Amerada Petroleum Corporation to accept a position in the geological department of the Producers and Refiners Corporation at Tulsa, Oklahoma.

U. R. LAVES has resigned from the Shell Petroleum Corporation and is now resident geologist for the Tidal Oil Company at 313 Shawnee National Bank, Shawnee, Oklahoma.

COLIN C. RAE has resigned his position with the U. S. Geological Survey at Okmulgee, Oklahoma, to join the geological staff of the Skelly Oil Company at Tulsa, Oklahoma.

W. W. RUSK, of the geological department of the Producers and Refiners Corporation, has been transferred from Parco, Wyoming, to Tulsa, Oklahoma.

PHILIP S. SCHOENECK is district geologist for the Atlantic Oil Producing Company, at 204 Lester Fisher Building, Big Spring, Texas. Mr. Schoeneck's district comprises the east side of the Permian basin.

G. L. ROHRBACH is doing geological work for the Adams Royalty Company, 303 National Bank of Commerce, Tulsa, Oklahoma.

The Fort Worth Geological Society has elected the following officers for the year 1929: president, R. A. LIDDLE; vice-president, A. R. DENISON; and secretary-treasurer, C. E. YAGER.

GEORGE FREDERICK KAY, of the University of Iowa, is vice-president of Section E (Geology and Geography) of the American Association for the Advancement of Science.

E. JABLONSKI, geologist for the Vacuum Oil Company at Houston, has been transferred to San Antonio, Texas, where he has an office in the Travis Building.

P. F. SHANNON, recently professor of petroleum engineering at the Colorado School of Mines at Golden, has gone to Colombia, South America, for the Tropical Oil Company.

ERNEST MARQUARDT, vice-president and chief geologist of the New York Oil Company, of Casper, Wyoming, and Los Angeles, California, has been in Paris during the winter.

JOSEPH H. SINCLAIR spoke at the annual meeting of the American Geographical Society, held in New York on January 22, giving a description of the

journey made by himself and Mrs. Sinclair in 1927-28 to eastern Ecuador. The geographical features of the expedition will be published in the *Geographical Review* of April, 1929. The description of the geology is being prepared for publication.

JOSEPH H. SINCLAIR states that a magnificent bibliography of the geology of Egypt, listing 205 works, all found in the New York Public Library, is published in the Bulletin of the New York Public Library, Volume 33, No. 1 (Jan., 1929), pp. 38-47. Photostat copies of the bibliography can be obtained from the library at a moderate price.

JOHN F. KINKEL has resigned from the Sinclair Oil and Gas Company to accept a position with the Independent Oil and Gas Company as resident geologist at Wichita, Kansas.

C. A. HEILAND, professor of geophysics at the Colorado School of Mines, Golden, Colorado, gave a series of lectures in geophysical prospecting at Columbia University, New York City, in February and March. The courses comprise torsion-balance, magnetometer, seismograph, and electrical prospecting, and were given from the beginning of February up to the middle of March.

HASTINGS MOORE and NATHAN I. MOYSE, geologists, announce the removal of their offices from 308 Wright Building to Suite 501, Philtower Building, Tulsa, Oklahoma.

L. T. BARROWS has succeeded EUGENE HOLMAN in charge of the land and geological departments of the Humble Oil and Refining Company at Houston, Texas.

E. W. SHAW is chief geologist for the Turkish Petroleum Company of London.

C. S. CORBETT is assistant to J. VOLNEY LEWIS in the New York office of The Gulf Companies at 21 State Street.

CHAS. E. STRAUB, who until a few months ago was geologist in charge of activities of the Dixie Oil Company in Kansas, has opened offices at 1102 Brown Building, Wichita, Kansas.

T. O. BOSWORTH, consulting geologist, died on January 18, 1929, at London.

RICHARD LEE MANNEN, 323 Bushnell Place, San Antonio, Texas, has returned after spending ten months with the Cameron Cadle Kalahari Desert Expedition into South Africa.

ALEX W. MCCOY, vice-president of the Marland Oil Company of Oklahoma, in charge of the land and geological departments, resigned his position in February.

F. J. MILLER, geologist in charge of the Louisiana-Arkansas district for The Texas Company at Shreveport, Louisiana, has resigned to accept a position with the Arkansas Natural Gas Corporation at Wichita, Kansas.

President R. S. MCFARLAND and vice-president DAVID DONOGHUE were in Austin, Texas, in February, in connection with the hearing of the Texas legislative committee on Criminal Jurisprudence on the bill proposed to require geologists to secure written permits from property owners before making geological examinations.

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